SECONDARY SCIENCE for Tropical Schools

BOOK TWO

J. H. PHEASANT

J. D. CLARKE

Formerly Inspector of Education, Nigeria

SECONDARY SCIENCE FOR TROPICAL SCHOOLS

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Secondary Science

FOR TROPICAL SCHOOLS

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BOOK TWO

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CHAPTER 1

Water and Living Things

THE WATER CYCLE is the name we give to the continuous movement of water rising as vapour from the sea and falling as rain on to the land, where it flows back to the sea again (Fig. 1). Without this ceaseless movement of water all land animals and plants would die.

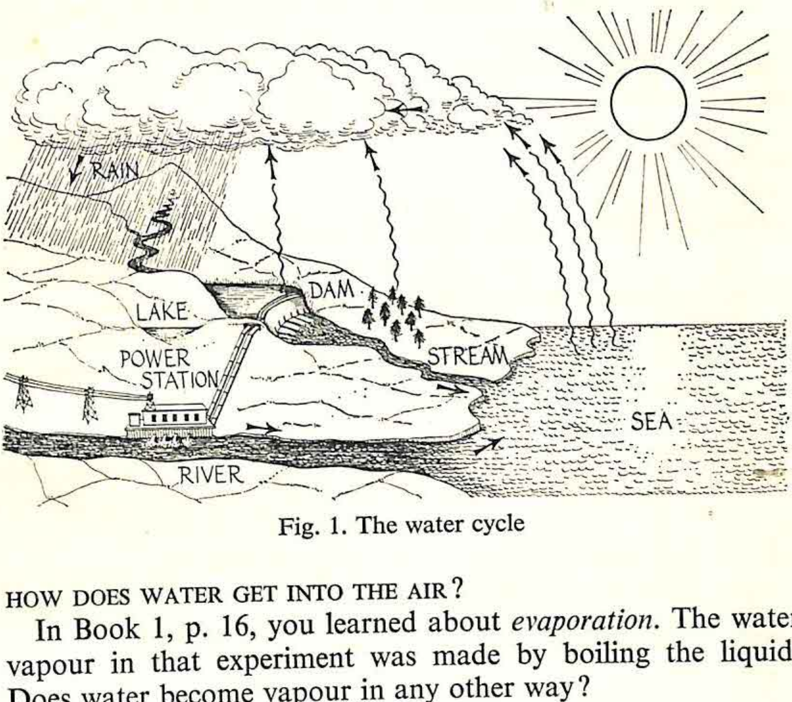

Fig. 1. The water cycle

HOW DOES WATER GET INTO THE AIR?

In Book 1, p. 16, you learned about *evaporation*. The water vapour in that experiment was made by boiling the liquid. Does water become vapour in any other way?

Half fill a test tube with water. Mark the level of the water with a piece of gummed paper. Pour the water from that test tube into a saucer and fill the test tube again to the same level. The test tube and saucer now contain equal volumes of water. Place both the test tube and the saucer in the sun. Note the time taken before the water evaporates in the saucer and in the test tube. Calculate the surface area of the water in the saucer and in the test tube. Is there any relation between the rate of evaporation and the area of the two surfaces?

Place one drop of water on each of two saucers. Put one in a warm but shaded place: put the other on a stand inside an earthen pot used for cooling drinking water (also in shade). Time the rates of evaporation of the water on the two saucers. Which was faster? Was direct sunlight necessary for evaporation?

WHAT ELSE AFFECTS THE RATE OF EVAPORATION?

Place a saucer at each end of a bench or a long table and put one drop of water carefully on to each saucer. Protect one saucer from air movement by covering it with mosquito net. Fan the other saucer steadily and note the time taken for the evaporation of the drop of water in each saucer.

From such experiments it can be shown that water in contact with air evaporates at all temperatures and that evaporation is more rapid in warm or in moving air.

In parts of the tropics near the sea there is very much water vapour in the air, particularly during the rainy season. We say that the air is very humid. During the dry season the humidity is lower but even over the Sahara Desert there is always some water vapour in the air.

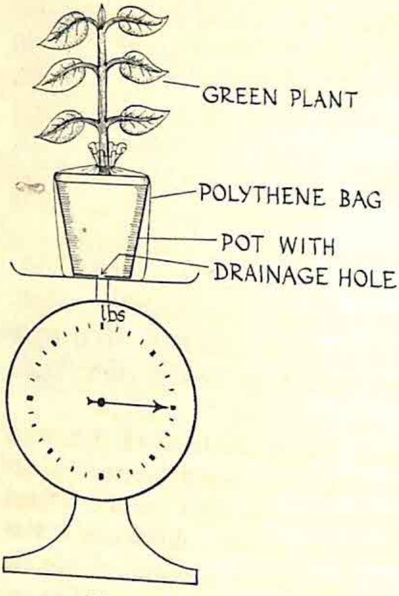

Fig. 2. Transpiration

TRANSPIRATION

In Book 1, p. 82, you saw that if you covered a growing plant with a polythene bag, drops of water appeared on the inside of the bag when the plant was standing in sunlight. This passing of water out of a plant is called *transpiration*. Let us now see how much water passes through a plant. Take a healthy plant (e.g. a Balsam) growing in soil in a pot. Water and drain it very well. Then put the pot in a polythene bag and tie the bag around the stem to prevent evaporation of water from the soil in the pot (Fig. 2). (1) Place the pot on a balance. Record the weight and note the time. Leave the pot on the balance in the sun for two hours. Read the weight again. Is the weight more or less than before? By how much? (2) Repeat the experiment putting the pot and balance in a shady place. Again notice the difference in weight. (3) Repeat the experiment, putting the pot in a dark room (or by covering it with a box).

The result of this experiment shows that transpiration differs from evaporation which goes on both in sunlight and in the dark. On the other hand, you have learned that both transpiration and evaporation require the heat energy of the sun.

It has been estimated that an acre of maize will give out by transpiration more than a thousand tons of water in a growing season. Calculate the number of inches of rain required to put that amount of water into the soil. [1 in. rainfall = 52 gallons per 100 sq. ft. = 22,000 gallons per acre. 1 gallon of water weighs 10 lb.].

Consider the number of acres in a square mile; and the number of square miles in your country. Then you may begin to understand the vast amount of water which is put into the air by transpiration from all the plants of the savannah, the rain forest and the farms.

You know that Health Officers do everything that they can to drain the swamps where mosquitoes breed around towns in tropical countries. Have you seen that in the land around the drainage channels they sometimes plant eucalyptus trees, the Blue Gum trees from Australia? Why do you think they plant these trees in damp places?

CONDENSATION

You have seen that water gets into the air by evaporation from ponds, dams, rivers and from the sea; and by transpiration from all the plants of the land. Turn to Book 1, p. 17. There you saw that when water vapour touches a cold surface it forms drops of water on that surface. The vapour condenses and becomes water again.

If you put very cold water or iced fruit juice into a tumbler what do you see on the outside? Test it with white copper sulphate. What was the liquid on the outside of the tumbler? From where did it come?

In the early morning after a very cool night, the grass is often very wet even when there has been no rain. We say that there is *dew* on the grass. This dew has not fallen from the clouds like rain. Most of it is water vapour from the surrounding air which has condensed on the cold grass.

Most of the water which passes into the air by evaporation and transpiration rises as an invisible gas until it reaches cold layers of air. There it condenses to form masses of very small drops of water. These masses can be seen near the ground on a cool morning in the rainy season when they form *mists* in the forest valleys. As the sun rises, the white mist rises too. Meeting warmer air it evaporates again. It is carried up until it condenses in the colder air to form the clouds. In Book 1 you learned about the lifting power of warm air currents. It is the rising currents of air which lift up the great weight of water put into the air by evaporation and transpiration.

The amount of water vapour in the air is one of the most important causes of weather changes. Air which contains as much water vapour as it can hold at a certain temperature is said to be *saturated*. If more water vapour is added to it the surplus will form a cloud or a mist, or it will settle on colder surfaces as dew. When air is warm it can hold more water vapour without being saturated than it can when it is cold. That is why air is more humid in the tropics than it is in temperate regions.

The largest source of water vapour is in the seas and the oceans which surround the land areas of the world. Look at them on a map of the world. How does the water evaporated from the seas reach your country? From which direction do the rain bearing winds and the dry winds come to you? From where do the cold winds and the hot dry winds come? Look at the map again and try to imagine which are the rain bearing winds in East Africa, in Europe and in other places.

Water evaporates from the seas and is carried up as vapour by rising air. Then it is carried along by wind for great distances until it comes out of the air on to land or sea as rain. On land, water flows slowly down to the sea. So there is a continual movement of water: down to the sea, up into the air. The water cycle goes on and on.

In the Geography lesson you may discover why the water cycle brings more rain in some months of the year than in others and why it is that some places receive more water than others.

YOUR WATER SUPPLY

Water is essential for all living things. It is not always easy to find both a safe and sufficient supply. Rain falls on the hills. Some of it sinks into the ground. Some of it flows on the surface. Water is a powerful solvent and many of the things which are dissolved by rain water, as it passes through the soil and into the rivers, are harmless. Some of them, in small amounts, give water a pleasant taste and provide the human body with materials such as calcium and iron which it needs for growth. Some things found in water, however, such as harmful bacteria and other living things, cause deadly diseases. Typhoid fever, dysentery, cholera, bilharzia and Guinea worm are waterborne diseases. Find out how each of these diseases is caused.

Even rain water contains gases and dust from the air. The only pure water is that which can be made by boiling some impure water and condensing its steam (Fig. 3). With a microscope compare a drop of river water with a drop of condensed water (also called *distilled* water).

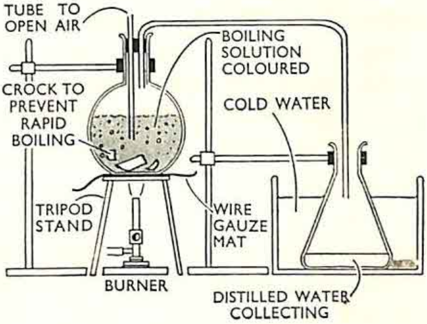
TUBE TO OPEN AIR
BOILING SOLUTION COLOURED
CROCK TO PREVENT RAPID BOILING
COLD WATER
TRIPOD STAND
WIRE GAUZE MAT
BURNER
DISTILLED WATER COLLECTING

Fig. 3.

Water for drinking and washing is generally obtained from (*a*) rain water tanks; (*b*) lakes, ponds and dams; (*c*) springs, streams and rivers and from (*d*) wells and waterholes.

All these sources of water are dangerous unless proper care is taken when using them. Rainwater is fouled by birds, rats, and other animals on the roofs from which it is collected.

Lakes, ponds and dams are safer sources of supply, for the sun and air are bacteria killers, but water from them is often made unsafe for drinking because it is collected in dirty buckets by people who walk into the water with dirty feet.

Springs, streams and rivers, also, are often unsafe sources of drinking water because people have used the streams for washing clothes and for defaecation.

Wells may be either shallow or deep. A shallow well collects water from soil near to the surface. This water is unsafe if it is mixed with dirty water from around the well top or from other places such as manure heaps, latrines, dye pits and so on. In deep wells also water is made unsafe by people bathing or washing clothes or spitting around the well top and by letting down dirty buckets into the well.

Deep wells can be a safe source of water supply if they are lined with concrete so that water only enters from the bottom and if the water is pumped up into a tank or to taps away from the well top.

Well tops should be built up to three feet above ground level and the ground around the top should be concreted for at least six feet from the edge of the well.

All water for drinking should be boiled. Even if water comes in a piped public supply there may be cracks in the pipe and harmful bacteria and other causes of disease may enter the water. Water must be kept safe for drinking all the way from the source to the consumer. As it is very difficult to do this in the tropics it is wise to boil water before drinking it.

Filtering water gives a false feeling of safety. Filtering alone is dangerous. For it is difficult to keep filters free from harmful bacteria. Filtered water may look clean but may be very dangerous. With a microscope, look at samples of water which have been filtered. Water should always be boiled even after filtering if it is to be used for drinking.

Water which has been boiled for drinking should be stored in bottles or metal drums which have been washed out with boiling water. Drums should be covered and have taps for drawing off water. If drinking water is stored in large pots, they should be covered. Any ladles used for dipping out water must be kept in a clean covered pot. A dirty mug must never be held in an unwashed hand and dipped into clean drinking water.

THE WORK OF WATER IN PLANTS AND ANIMALS

You have already learned that water vapour is given out by the leaves of plants. Note what happens to a young Balsam plant on a hot day if its roots cannot get plenty of water or to any cut branch of a plant such as Hibiscus if it is given no water. When a plant is taking in enough water its leaves stand erect and stiff. If a plant gives out more water than is taken in, its leaves droop and it is limp. It is not in a healthy state. If it has not been limp for long, however, a plant quickly recovers when it is put in water. Soak the soil around the Balsam and observe the effect on its leaves.

WATER IN THE HUMAN BODY

The human body in health seems to be very strong and solid. In fact, about three-fifths of your body weight is water. Weigh yourself and calculate the weight of water in your body.

The water we drink is needed to help the body to work properly.

The liquid part of the blood is largely water. Sufficient water must be taken in to the body to keep up the supply of blood needed for all the work listed in Book 1, p. 97. Water is needed also to wash waste substances out of the body. All the time we are alive, waste substances collect in various parts of the body. They would be very harmful if they were not quickly removed.

These waste substances are of two kinds:

(1) There is the waste matter in the bowel, the part of our food which is not digested. It is merely passing through the body. Water is needed so that this waste matter may move easily. If it is too dry, you will become constipated. Plenty of water should be drunk to move the waste matter from the bowel.

(2) There are waste substances such as urine, perspiration and the gases given out in breathing. These have been formed in the body and will do harm if they remain there. The removal of these waste substances is called *excretion*. (Note well: it is not correct to call the waste matter from the bowel, excreta. Such matter is more correctly named, faeces, the product of *defaecation*, which is one of the ways in which waste substances leave the body).

Boil a little perspiration to dryness. Test the vapour which is given off with white copper sulphate. You will hardly see the other substances which are such a small part of perspiration. You have already seen that there is water in the mixture of gases given out in breathing (Book 1, p. 61). It is clear, then, that much water must be taken in to replace what is lost in excretion.

EXCRETION

All the time you are alive the living jelly called protoplasm which forms a large part of every cell (Book 1, p. 68) in your body is continually wearing out. New protoplasm must be formed to replace that which has done its work. The protein food we eat (meat, eggs, fish, beans, etc.) builds up new protoplasm. The worn out protoplasm breaks down into a watery liquid which passes into the blood and is carried to the kidneys to be excreted from the body.

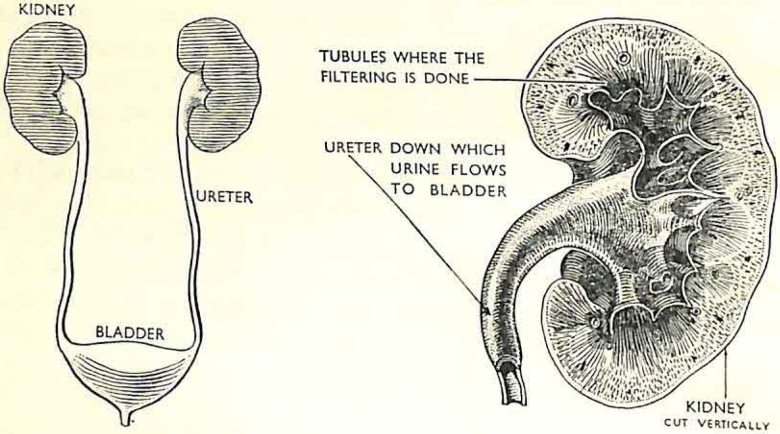
KIDNEY
URETER
BLADDER
TUBULES WHERE THE FILTERING IS DONE
URETER DOWN WHICH URINE FLOWS TO BLADDER
KIDNEY CUT VERTICALLY

Fig. 4. The kidney system showing one kidney cut in half

There are two kidneys in the human body and in the bodies of many animals. They are bean shaped (Fig. 4) and lie in the narrow part of the back. Blood containing waste substances is brought to each kidney by an artery and is filtered as it passes through the kidney. Useful substances such as the plasma (Book 1, p. 97), corpuscles and sugar are kept in the blood.

The waste liquid and some salts are filtered off and pass down two tubes into the bladder. When the bladder is full, this waste liquid or urine leaves the body in urination.

It is very important that the kidneys filter all the waste products from the blood. If the kidneys are diseased or overworked, the waste material remains in the blood and poisons the living cells of the body. If this continues, the body dies. When we are ill, there is much waste matter in the blood. This must be filtered out by the kidneys. Drugs given by the doctor must be washed out of the body after they have done their work. So, it is very important during illness to drink plenty of water and fruit juices. This helps to wash waste matter out of the kidneys and to prevent them becoming damaged.

The skin also plays an important part in excretion. Through it, waste liquid is removed from the body in sweating or perspiration. (These two words mean the same thing.) Near some of the very small tubes through which blood flows in the skin, there are some other little coiled tubes called sweat glands. Some waste liquid passes from the blood into the sweat glands and leaves the body through the skin. When the body is very hot more liquid is lost by perspiration and less is lost as urine from the kidneys. Men who work underground in coal mines lose large amounts of water and mineral salts in perspiration. So, they are often given water to drink to which salts have been added to replace those which they have lost.

It is very necessary at all times to keep the skin clean. If it is dirty, waste liquids cannot pass out of the skin and so harmful substances remain inside to poison the body. Therefore plenty of water should be used to keep both the outside and the inside of the body clean. Water should be drunk freely in hot weather not only to replace the water lost through the skin but also to flush the kidneys properly.

PERSPIRATION AND THE TEMPERATURE OF THE BODY

Why do we perspire? Not all animals have sweat glands. The kidneys could quite well deal with all our waste liquids. There must be a reason why we get rid of waste water through the skin.

One of the things outside our body which makes us uncomfortable is hot air. In the tropics the air is often very hot. The very small blood capillaries near to the surface of the skin become wider and waste liquids are poured into the sweat glands. From these glands, it spreads over the surface of the skin as perspiration. When the perspiration evaporates it cools the body (Book 1, p. 25). If your body temperature rises much above your normal temperature you are ill. The quicker the perspiration evaporates on your skin the more you are cooled. In places where there is already a lot of water vapour in the air, perspiration does not evaporate quickly so we use fans. A fan makes air pass more quickly over the damp skin and increases the speed of evaporation. It is much easier to keep cool when the air is dry, because dry air increases evaporation. In fact, during the season when dry winds blow from inland regions, the body may feel too cold.

The answer to the question 'Why do we perspire' is clearly that perspiration helps to control the temperature of the body.

WATER AND REPRODUCTION

Water is very important in all animal reproduction. Most female animals produce eggs which must be fertilised by sperm from a male animal before their young can be produced. There must be water so that the sperm may swim towards the egg. When the egg is fertilised it is called an embryo. The early stages of the growth of the embryo are very soft and might easily dry up if they are not provided with sufficient water. All the methods of reproduction which will be described now have one aim. It is to ensure that the embryo does not dry up.

The simplest forms of life are found in water. They reproduce themselves by division. An Amoeba, a very small animal which lives in the soil, in ponds and in the sea, reproduces in this way: one splits and becomes two; those two split again and become four separate living things. The warm water or damp mud in which they live suits this form of reproduction. Many plants and animals which are very much less simple than Amoeba live and reproduce in water. Many female fishes, for example,

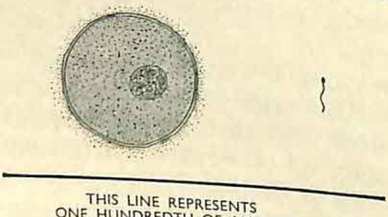

Fig. 5. Fish egg and sperm

pass their eggs out into the water. The male makes large numbers of cells called sperm which swim about and join with the eggs (Fig. 5). When that happens an egg can grow into a young fish. If an egg is not fertilised by a sperm it dies.

Toads pass their eggs and sperm into water but the males and females pair up before the eggs are laid. As the eggs (called spawn) are laid in the water, the male pours his fertilising liquid which contains sperm over them. While the eggs are being laid the male sits on the back of the female clasping her firmly with his forelegs. This is a surer method of fertilisation than that of most fishes but as the parent toads take no care of the fertilised eggs afterwards many of the young die. It is a wasteful method of reproduction.

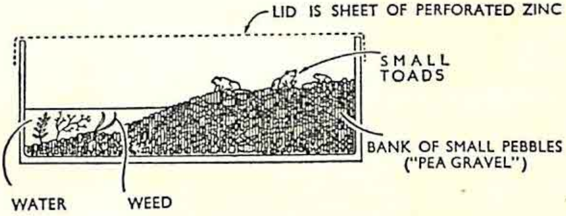
LID IS SHEET OF PERFORATED ZINC
SMALL TOADS
BANK OF SMALL PEBBLES ("PEA GRAVEL")
WATER
WEED

Fig. 6. A home for young toads

After fertilisation, the thin jelly covering a toad's egg swells and protects the growing young animal from drying up and from other animals which may try to eat it. Collect some spawn from a pond or small stream. Put it in large jars or in a glass tank of water and watch the development of the tadpoles (as the young of toads are called). The tank should have at least an inch of washed sand and small stones at the bottom. Collect some green water weed and lightly tie the roots to a stone and place it in the sand (Fig. 6).

Note that as the young tadpole develops, the inner part of the jelly turns to a liquid and the animal swims for a short time in its own little pool. You will be able to see the tadpole move out of its jelly bag into the water. The eggs of fishes and toads contain enough food to keep the young alive until they can find food for themselves.

Birds and some other animals, such as lizards, snakes and crocodiles, lay eggs. These eggs are larger and contain more food than the eggs of fishes and frogs. They are land animals and their eggs have hard shells to prevent them from drying up. So fertilisation has to take place before the hard shell is added to the egg. It takes place inside the body of the female. The male and female pair off. The fertilising liquid of the male containing sperms passes into the female's body. Each of her eggs as it passes down the egg tube is fertilised by a sperm before the hard shell is put round it. Then the egg passes out of the female's body.

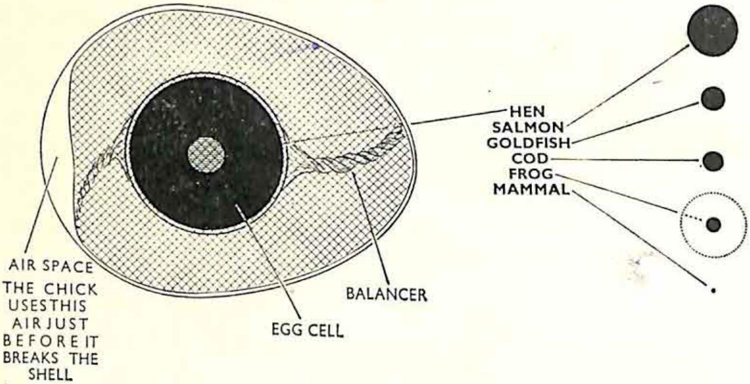

Fig. 7. A hen's egg and the sizes of some other eggs

The egg must be kept at a high temperature while the young animal inside is developing. Among birds it is usually the female which sits on the egg to keep it warm. The growing chick inside floats on top of the egg liquid and so is nearest to the warm body of the hen. When the young chick has used up all the food provided in the egg, it cracks its way out of the egg and is 'hatched'. Look for lizards' eggs and note where they are placed by the female. Place some in sand and keep them in a warm place to note the time of hatching.

REPRODUCTION IN MAMMALS

Most mammals (Book 1, p. 73) live on land and their eggs must be protected and their contents kept moist. The mammals have found the surest way of fertilising eggs and caring for the young animal as it develops. By means of a tube, called the

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penis, the sperms are placed inside another tube leading to the two oviducts (the egg passages) in the female's body. The lower part of this tube is the vagina. The upper part is swollen to make a larger tube, the uterus or womb. Only a few eggs are produced at a time. If a sperm is able to swim towards one of the eggs and to enter it, the egg will be fertilised.

In most mammals, including human beings, the fertilised egg fixes itself to the wall of the uterus and develops there. The egg is very small. It does not contain a lot of food. Food is brought to the wall of the uterus in the mother's blood and the food (but not the blood) passes through the mass of cells which fixes the young mammal to the wall. This mass of cells is the placenta. Through the placenta, also, waste substances pass from the young mammal into the mother's blood (Fig. 8).

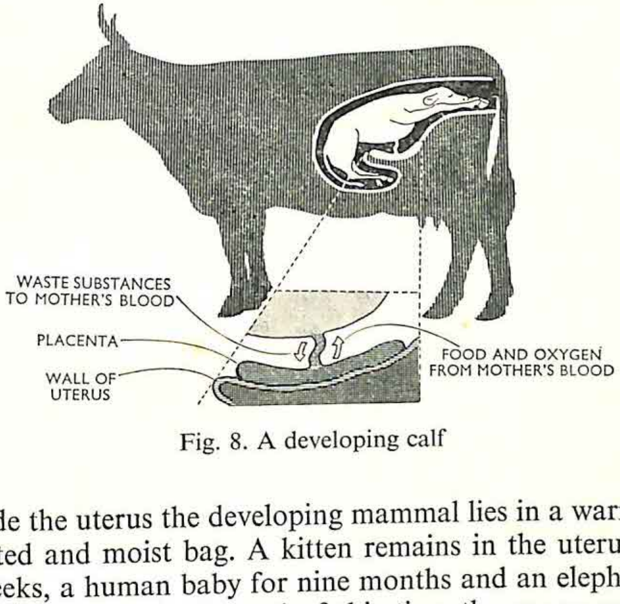
WASTE SUBSTANCES TO MOTHER'S BLOOD
PLACENTA
WALL OF UTERUS
FOOD AND OXYGEN FROM MOTHER'S BLOOD

Fig. 8. A developing calf

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Inside the uterus the developing mammal lies in a warm, well protected and moist bag. A kitten remains in the uterus for a few weeks, a human baby for nine months and an elephant for nearly two years. At the end of this time the young mammal passes down the tube leading from the mother's body to the outside world. After it is born the young mammal has to get used to very different surroundings. It has to use its lungs to breathe instead of getting oxygen from its mother's blood. It has to feed itself by sucking milk.

S.C.E.R.T., West Bengal
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PLANTS AND ANIMALS WHICH LIVE IN WATER

You have seen that water is needed for the reproduction of living things and you know that it is necessary for their health. Let us now briefly look at those animals which live in water. Fishes, of course, are most at home in it for they do not have to come to the surface to breathe air. They have gills on each side of the throat. Water, in which air is dissolved, passes over the gills and, as it does so, some of the oxygen is taken into the fish's blood stream. Note also how well suited the shape of the fish's body is to life in water; how with one or two flips of its tail, it can move away at high speed when frightened.

Many birds only come on land to lay their eggs and to rear their young. During the other months of the year they are at sea and often remain far from land. There are other birds which live only along the sea shores and river banks: some are fish eaters, while others, known as waders, find their food at the water's edge. See whether you can list some of these water birds.

There are some large mammals which live in water like fishes but have to come to the surface to breathe: the whales, the dolphins, and the porpoises of the oceans and the manatees of tropical rivers. They all breathe like land mammals, they produce their young and suckle them similarly but they swim in very much the same way as fishes.

STUDY THE PLANT AND ANIMAL LIFE IN A POND (or on the sea shore if you live near the sea).

If possible make an aquarium for the living things you find. You will see that some of the water animals live on weeds and dead plant material and some eat other animals. (The latter must be kept in separate jars). Choose one animal for special study and try to find out by careful watching

(1) what it looks like (make a drawing),
(2) how it moves,
(3) how it feeds, and
(4) how it reproduces.

WATER IS A SUPPORT FOR LIVING THINGS

Look back to Book 1, p. 65, to see how green pond plants provide oxygen for water animals to breathe. Note how they are held up by the water in which they live.

See how easily a fish swims and how helpless it is when out of water. Very heavy animals such as the hippopotamus (the 'horse of the river') move clumsily on land but can leap like young goats in the Niger River. These plants and animals are held up by the water in which they live.

MAKE A POND BOOK

If each pair of pupils in a class studied one pond animal or one plant carefully and wrote up the result of that study you would make a very useful book for the school library.

SUMMARY

While working through this chapter you have learned about some of the ways in which water is important to living things; about the essential role of the water cycle and the part played in it by evaporation, transpiration and condensation; about your water supply; about the water in human and animal bodies and its excretion; about the need for water in reproduction and about some plants and animals which live in water.

THINGS TO DO

(1) On a hot dry day get a friend to weigh you carefully (perhaps, on a produce scale). Then go for a walk or work in the garden for an hour. At the end of that time have yourself carefully weighed again. The difference in weight will be mainly due to the water lost in perspiration. Find out how much water you will have to drink to regain your original weight.

(2) Name six animals and six plants which live in ponds or streams in your district.

(3) Make a plaster cast of the footprints of a bird or other animal on the sea shore or river bank. (Place a ring of cardboard or tin around the footprint. Mix some Plaster of Paris to a thin paste and immediately pour it into the ring and let it set until hard.)

(4) List the purposes for which water is used in your home every day.

(5) Repeat the experiment with the Balsam plant (on page 10). After noting the weight of water which has passed through the plant in two hours, carefully lift the whole plant and wash all

the soil from the roots without damaging them. Then weigh the plant.

(6) Repeat the experiment with other plants (e.g. zinnia, a young maize plant, a tomato plant and so on) to see whether the the rate of transpiration is greater in one species of plant than another.

QUESTIONS

(1) In temperate regions, skies are often cloudy. Why is there more sunshine in the tropics even though there may be more water vapour in tropical air than there is in the air of temperate regions?

(2) What effect on land temperatures do winds have in the tropics?

(3) What are the directions of the rain bearing winds and of the dry winds in your district?

(4) Explain how clouds are formed.

(5) What makes rain? What is the cause of dew?

(6) Why is it dangerous to drink water from a river?

(7) Why should you drink plenty of clean water?

(8) How could you show that dew does not fall from the clouds like rain?

CHAPTER 2

More about Water

THE COMPOSITION OF WATER

You have learned about the three states in which substances are known: solids, liquids and gases (Book 1, p. 15). There is another important way in which substances differ: some are elements while others are compounds of elements. An *element*

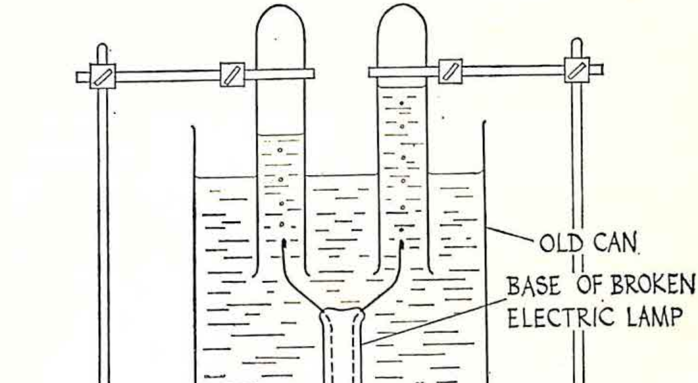

Fig. 1. Splitting water to get Hydrogen and Oxygen

is a substance which cannot be split up into anything simpler than itself. A piece of iron, for example, is made of iron and of nothing else. A liquid such as the mercury used in thermometers is an element and cannot be split up into other substances. The gases, oxygen and nitrogen, are also elements.

A *compound* is a substance in which two or more elements are united. For example, chalk is a compound of three elements: one atom of calcium, one atom of carbon and three atoms of oxygen. Similarly, water is a compound: two atoms of the gas hydrogen, join with one atom of the gas, oxygen, to form a molecule of the liquid which we call water.

The apparatus in Fig. 1 may be used to split up water into the simple elements of which it is composed. Fill the can with water and add a few crystals of common salt. Connect the two wires to a car battery. What do you see coming from the ends of the two wires in the water? Fill a test tube with water. Then with a finger covering the open end of the test tube turn it upside down. Lower it into the can so that it is above one of the wires. Clamp the tube in a stand. In the same way clamp a test tube of water over the other wire. What happens to the water in the test tubes? When one of the test tubes is full of gas, disconnect the wires from the battery. Cover the end of that tube with a finger. Remove it from the water. Hold a lighted splint near the mouth of the tube. Note how the gas burns. What happens when it burns? This gas is hydrogen.

Now look at the other test tube. How much gas does it contain? Test the gas in the second tube with a glowing splint (Book 1, p. 53). What is the gas in this tube?

You have seen that the electric current from a battery passing through water, causes some of it to split into the simple elements hydrogen and oxygen.

WATER IS PRODUCED BY BURNING

You know that iron unites with oxygen from the air to form the new substance *rust* or iron oxide. Similarly, the burning of hydrogen in air produces the hydrogen oxide which we call water.

Set up a kettle as in Fig. 2 with cold water running through it. Put a Bunsen flame under it. What can you see on the underside of the kettle? Test the drops of liquid with white copper sulphate (Book 1, p. 55). When candle wax or coal gas are burned, the hydrogen in them joins with oxygen in the air to produce water.

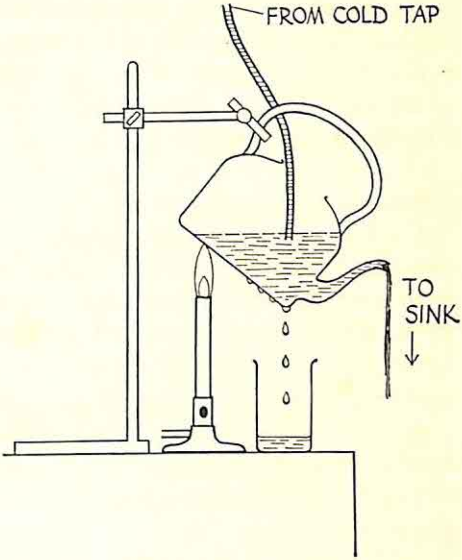

Fig. 2. Burning joins Hydrogen and Oxygen and makes water

THE PREPARATION OF HYDROGEN

When you passed an electric current through water, some of the water was split up into the two gases, hydrogen and oxygen. Hydrogen may also be produced by splitting up dilute sulphuric acid, which is a compound of the elements sulphur, hydrogen and oxygen. Zinc is an element which acts upon sulphuric acid, setting free hydrogen.

Set up apparatus as in Fig. 3. Put some pieces of zinc into a flask. Pour some dilute sulphuric acid down a thistle funnel until it covers the zinc and the end of the tube. Collect over

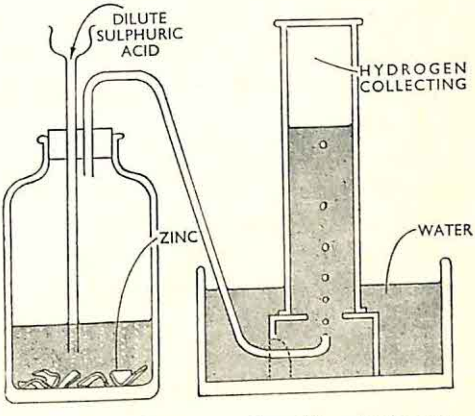

Fig. 3. Another way of making hydrogen

water some of the gas produced. Test a jar of the gas with a lighted splint. Does it burn as hydrogen burned in the earlier experiment?

WARNING: it is dangerous to put a burning splint near the end of the tube leading to the gas jar.

IS HYDROGEN LIGHTER OR HEAVIER THAN AIR?

Fill two test tubes with hydrogen. Cork them and stand them in a rack. Remove one cork and wait for half a minute. Remove the other cork and *immediately* hold lighted splints to both tubes. Does the gas burn in both tubes? What happened to the hydrogen in the tube which was opened first? Note that hydrogen and a little air make an explosive mixture.

WATER AS A SOLVENT

The following two experiments demonstrate the solution of a gas in water.

(i) Take a 1,000 c.c. flask fitted with a long delivery tube. Fill the flask and tube completely with water. Place a long narrow glass measuring cylinder also full of water over the end of the delivery tube. (Fig. 4). Heat the water in the flask. What do you see rising in the cylinder? The gas collected in the cylinder cannot be steam for it passes through cold water in

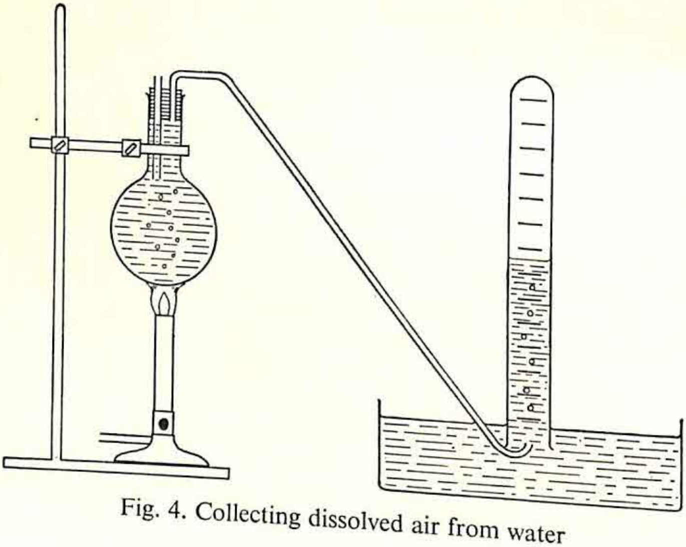

Fig. 4. Collecting dissolved air from water

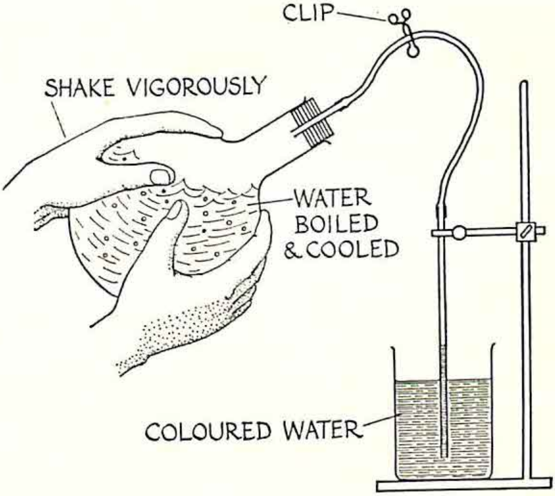

Fig. 5. Dissolving air in boiled water

the trough and displaces cold water from the cylinder. Measure the volume of the gas in the cylinder. The gas has the properties of air. Boiling the water has driven out the air which was dissolved in it.

(ii) Measure 500 c.c. of water and put it in a 1,000 c.c. flask. Boil the water for at least three minutes to drive air out of it. Cork the flask and leave it to cool. With a one-hole stopper and some rubber tubing, connect the flask to a narrow glass tube standing in a beaker of coloured water (Fig. 5). Put a clip on the tube. Shake the flask well and remove the clip. Did the water then rise in the glass tube and if so, how do you explain the result?

DOES WATER DISSOLVE SOLIDS?

Take a beaker full of well water or river water. Filter it. Boil the filtered liquid until it is almost completely evaporated. Then pour it into an evaporating dish and continue boiling until the dish is almost dry (Fig. 6). What do you see in the dish after it has cooled and the water has evaporated?

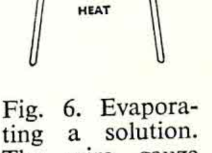

Fig. 6. Evaporating a solution. The wire gauze mat spreads the heat and protects the dish

The solid substance in the dish had passed through the filter paper: it was dissolved in the water.

Because there is so much water and because it dissolves so many substances it is the most important solvent in the world.

ARE ALL SUBSTANCES EQUALLY SOLUBLE IN WATER?

The following experiments will answer that question and give you practice in accurate weighing.

Weigh an empty beaker. Put 100 c.c. of water into it and weigh it again. Add some common salt, a little at a time, stirring after each addition until no more will dissolve. Weigh the beaker again. How much salt has been dissolved in 100 c.c. of water? You now have a cold saturated solution of salt in water. ('Saturated' means 'completely filled').

This experiment may be repeated with other salts such as copper sulphate, washing soda, alum, and the 'hypo' used by photographers. Note how much of each salt is required to make a cold saturated solution in 100 c.c. of water.

THE EFFECT OF HEAT ON SOME SOLUTIONS

Make a cold saturated solution of copper sulphate. Add a little more of the copper sulphate. It remains undissolved however much you may stir it. Now heat it. What happens? Add some more copper sulphate and continue heating until no more will dissolve. You now have a warm saturated solution of copper sulphate in water. How would you find out the amount added after you began heating the solution?

Allow the solution to cool very slowly. Do not move it. The warm saturated solution contains more copper sulphate than cold water was able to dissolve. Watch what happens as the solution cools.

MAKING CRYSTALS

When the hot saturated solution cooled you found that some of the copper sulphate came out of the solution and formed solid particles. These can be filtered out of the solution carefully. Look at them with a hand lens. You will see that they are alike in shape. We call these definitely shaped particles, *crystals.*

To grow a big crystal take a small well-shaped crystal of copper sulphate, and, with a thread, hang it in the cold saturated solution. Look at it every day for a week.

There may be rocks in your neighbourhood which contain crystals. Break a piece of rock with a hammer and examine the broken surface with a hand lens. Perhaps you can imagine how those crystals were formed.

SUBSTANCES WHICH TAKE IN WATER

Dry some common table salt by heating it over a Bunsen burner. When it is cool, weigh it carefully. Then leave it uncovered for a day and weigh it again. What do you find? What has happened to the salt?

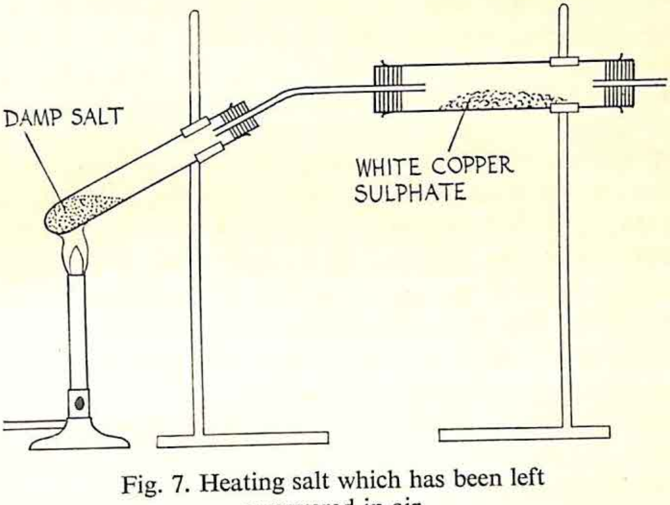

Fig. 7. Heating salt which has been left uncovered in air

Put some of it into a test tube. Connect the tube to another containing some white copper sulphate (Fig. 7). Gently heat the tube containing the salt. Note what happens to the white copper sulphate. Can you say what substance was taken in by the dry salt? This experiment may be repeated, using other substances such as sugar, unspun cotton and cement. These things take in water and must be packed in containers which protect them from moist air.

SUBSTANCES WHICH GIVE OUT WATER

Weigh a clean plate. Cover it with a layer of washing soda crystals. Weigh the plate and the soda. During the dry season leave it in the air uncovered for a week. Weigh the plate and its contents again. Are you surprised at the result of this weighing? How do you explain it?

Weigh a pound of fresh groundnuts or shea nuts or palm kernels. Store them for a month or longer in air and protect them from insect damage. Then weigh them again. Repeat this experiment using fresh yam, maize, cassava, etc. You will understand that the man who buys a ton of groundnuts in Africa may have only nineteen hundredweight when the bags are weighed in Europe. This is a loss which traders have to consider when fixing the price to be paid to farmers.

COOLING BY EVAPORATION

Revise the work on distillation in Book 1, Ch. 1. Let us find out more about what happens when water evaporates.

Wet a finger and hold it up in the air. Why does one side of that finger very soon feel colder than the other?

If you drink warm water on a hot day, you perspire freely. Why does this make the skin feel cool?

Fill two small and newly baked earthen pots with water. Note the temperature of the water in each pot. Stand one pot on a shaded verandah where there is free movement of air. Cover the other with a box or a larger pot. Note the temperature of the water in each pot at hourly intervals. Why is the temperature in one pot lower than in the other?

Why does the evaporation of water on your skin and on the side of a water pot lower temperature? To answer that question you must think of what happens when water evaporates. If you want water to evaporate quickly from a saucer or from a newly washed shirt you put it in the sun or near some other source of heat.

Heat is needed for evaporation. When evaporation takes place on your skin, heat is taken from your body. So you feel cool. The uncovered pot, on a windy verandah, cools more quickly than a covered pot for the wind takes away the water vapour quickly. Thus evaporation and cooling (i.e. taking heat out of the pot) go on at greater speed.

THE WEIGHT OF WATER

Weigh a beaker. Put 100 c.c. of water into the beaker and weigh it again. What is the weight in grams of 100 c.c. of water?

The scientists who first worked out the Metric system of weights and measures decided that their unit of weight, the gram, should be equal to the weight of one c.c. of pure water. This relation between the weight of water and its volume is very simple. Compare the Metric system in which 1 cu. centimetre of water weighs 1 gram with the British system, in which the weight of 1 cu. ft. of water is 62.5 lb. or 0.016 cu. ft. of water weighs 1 lb.

WEIGHT AND DENSITY

Weight is the amount of force by which something is attracted to the Earth. Two things which are equally attracted are equal in weight. One may be large, the other may be small but if they balance each other on a scale they are the same weight. A pound of feathers may fill a large bag, a pound of lead would not fill a cigarette tin. Both, however, balance a pound weight on a scale. They are equal in weight. They differ in volume. The *density* of a substance is its weight divided by its volume. The density of lead is greater than that of feathers.

THE DENSITY OF WATER

The weight of one cubic centimetre of water is one gram, therefore you can say that the density of water is 1 gram per cu. cm.

You can compare the density of substances by noting what happens when they are placed in water. Those which are less dense than water, float. Those which are more dense, sink.

Put 100 c.c. of water in a beaker and add to it 100 c.c. of kerosene. Which liquid has the greater density? Repeat the experiment using palm oil, cork, and a stone. Compare their density with that of water.

THE PRESSURE OF WATER

Water has pressure because it has weight. Pressure is not the same as weight, however, To understand the meaning of pressure, nail two pieces of wood together as in Fig. 8. Mix a little water with some clay to make a soft putty. Put it, to a depth

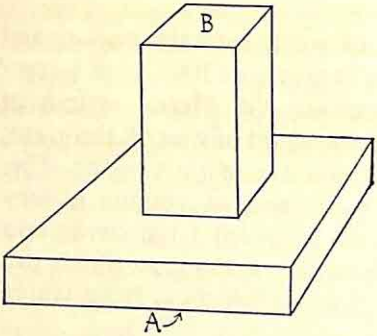

Fig. 8.

of about two inches, into a box and level the surface. Place the wood with surface A on the clay and put a 4 lb. weight on B. Leave it for a minute: then lift the wood and note the depth of the mark on the clay. Turn the piece of wood and place it with surface B on the clay. Put the 4 lb. weight on surface A. Leave for a minute: then again lift the wood and note the depth of the mark made on the clay. Compare the two marks. Note that, in this experiment, the two marks on the clay were made by the same weight. Why was the first mark deeper than the second?

The weight on each mark was the same: the pressure was different. On the first mark the whole weight was on 1 sq. inch of the clay. On the second mark, the weight was spread over 9 sq. inches. It is not surprising therefore that the first mark was much deeper than the second. *Pressure* is the weight per unit area. On the first mark, the pressure was about 4 lb. per sq. inch. On the second, it was about 4 lb. ÷ 9: that is, the pressure was less than $\frac{1}{2}$ lb. per square inch.

Weight is recorded in *lbs.* or *grams:* Pressure in *lbs. per square inch* or in *grams per square centimetre.*

The fact that pressure is greater when there is a greater height of water may be shown with the apparatus in Fig. 9. Connect the top of the apparatus to a water supply. Note the strength of the jets from each hole in the long tube. Note the point where each stream of water falls on to the ruler. Make a scale drawing and write in the measurements. Note (*a*) the hole from which the jet of water goes out furthest, and (*b*) the hole from which it comes out with the least force.

The height of water above the place where its pressure is used is sometimes called the 'head' of water. The greater the head of water, the greater is its pressure. If your water supply comes by pipe from a dam or spring on much higher ground, turn on the tap and try to stop the flow of water with one finger.

When water is stored in a dam, the greatest depth is usually near to the dam wall. Because there is a large head of water near the wall the pressure at the bottom is very great. How do the water engineers build a wall which will stand up to that great pressure at the base?

Pressure causes water to flow downwards. If it is not stopped it goes on flowing until it reaches the sea. In what ways in your own locality is this downward flow stopped?

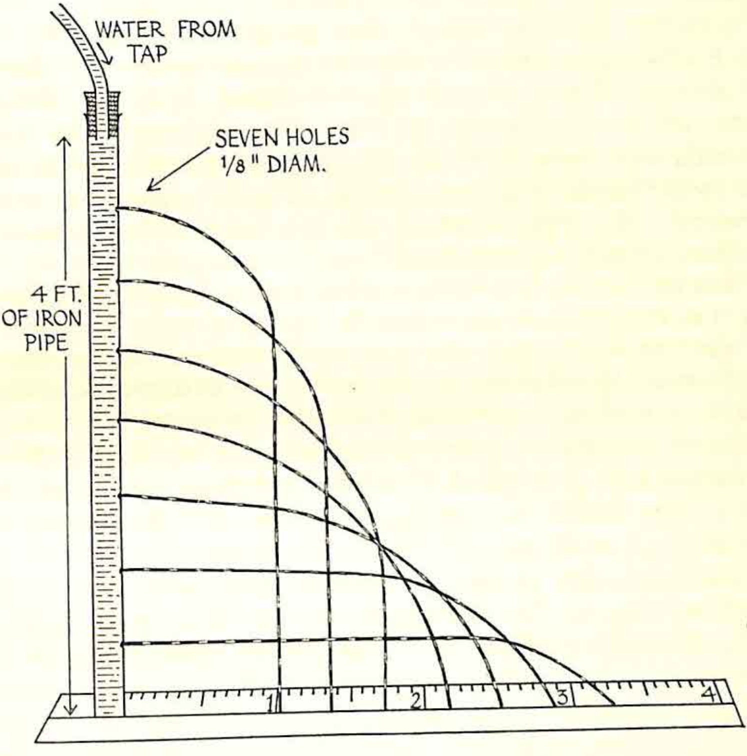

Fig. 9. Water pressure at various depths

You have seen that a large head of water produces great water pressure. Water may also be under pressure because there is a pump behind it. Take a bicycle pump. Dip it into a bucket of water and pull out the handle to fill it with water. Then push the pump handle in firmly. A jet of water comes out under pressure. Measure the distance you can reach with this water pump.

You learned in Book 1 that air is elastic: it can be compressed and it will expand again.

Fill the bicycle pump with water. Close the hole at the bottom by pressing it against a piece of rubber on a wall. Try to push the pump handle in firmly. What happens? Empty the pump. Pull the handle to fill the pump with air. Again, press the bottom of the pump against a piece of rubber and push in the handle. Is water elastic?

Join two pieces of narrow bore glass tubing about 20 cm. long with a short length of rubber tubing, and put some coloured water into them to a depth of about 10 cm. Hold the tubes in one hand so that the tops are level. Note the level of the water in each tube. Now raise one of the tubes a little and again note the water levels. Allow one tube to lie at an angle to the other and note the water levels in the two tubes. What have you learned from this experiment?

Fix the same two tubes to a stand with Terry clips. You have seen in the last experiment that the height of water in one tube is always equal to the height of water in the other. This apparatus with a liquid balancing at the bottom of two joined tubes is called a *manometer* and may be used to measure pressure.

With a length of rubber tubing join the top of one of the tubes to a 10 cm. funnel. Cover the mouth of the funnel with thin sheet rubber, sealing it at the edges with gum or rubber solution. Almost fill a bucket or a tall glass jar with water. Hold the funnel in the water mouth downwards near to the surface. (Fig. 10). Do you notice any movement of the liquid in the manometer? Now push the funnel right down to the

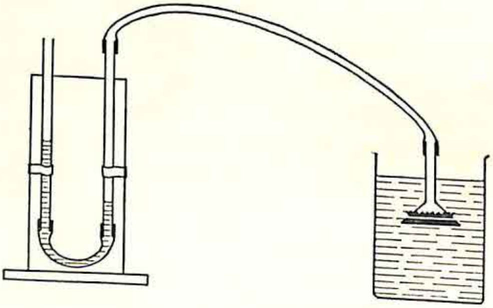

Fig. 10. To show water pressure

bottom of the water. Note the level of water in the manometer tubes. How do you explain the change in the water levels in the tubes? Does this experiment tell you anything about the pressure of water at different depths?

PRESSURE IN DIFFERENT LIQUIDS

With the manometer and funnel you may also compare pressure in liquids of different density. Almost fill a tall jar with water and pour kerosene or palm oil or a saturated solution of common salt into another jar until the surfaces of the liquids are level. Test the pressure at the bottom of each jar.

HYDRAULIC POWER

Make a little water-wheel (Fig. 11). Let water flow on to it from a glass tube.

The word *hydraulic* comes from Greek words meaning 'water' and a 'pipe'. A hydraulic machine is one in which power is carried through a liquid in a pipe.

Join a rubber hot water bottle (or football bladder) to a one-gallon tin by at least five feet of tubing (Fig. 12). Joints must be made with waterproof gum and should also be tied with wire or string. Place the rubber bottle, tube and tin on the ground and fill them with water. Put a small board on the rubber bottle. Put some heavy books on the board. Now raise the can and watch the board. What load can be lifted when the can is raised to the full length of the tubing?

The lifting power of water (or any other liquid) may seem surprising. The surface of the rubber bottle is approximately 50 square inches. It might be thought that the upward pressure on each of those square

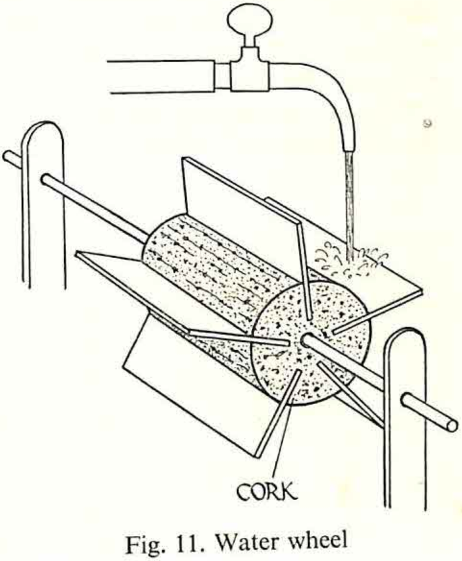

Fig. 11. Water wheel

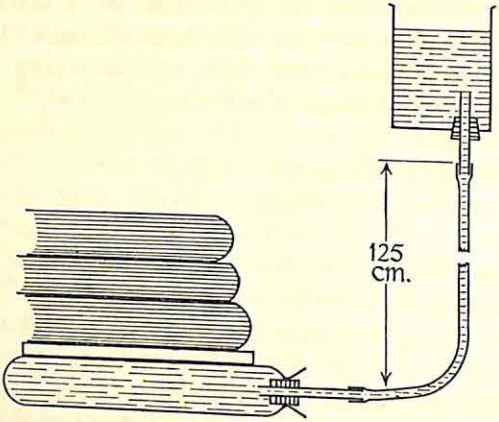

Fig. 12. Weight lifting by water pressure

inches would be 1/50th of the downward pressure in the tube. That is not what happens. The pressure of the head of water in the tube acts equally on every square inch of the lifting surface in the rubber bottle. If there is a pressure of 10 lb. per square inch at the bottom of the tube, then there is a total lifting power on the surface of the rubber bottle of 50 × 10 lb. (500 lb.).

Hydraulic pressure is used in great machines which press steel and aluminium to shape the bodies of motor cars and aeroplanes. It is also used for the lifting gear of farm tractors and bulldozers. You may have seen these machines at work and noted how easily the driver raises and lowers the plough shares and other tools used to move earth. The driver pulls a lever. Liquid is pumped through pipes; hydraulic pressure lifts the tools. In the experiment with the rubber bottle you saw how the pressure of a head of water could be used to lift a heavy load. In the next experiment you will see how the tractor driver uses hydraulic pressure.

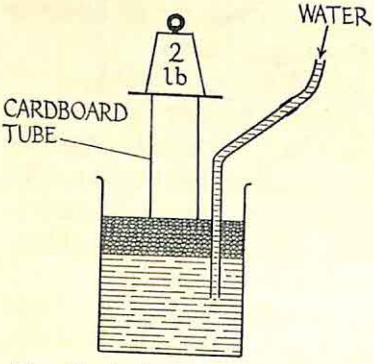

Fig. 13. A simple hydraulic lift

Half fill a tall cylinder with

water. Melt some beeswax or candle wax and pour it on to the surface of the water to a depth of at least an inch. Hold a piece of glass tubing in the wax while it cools. Join a bicycle pump to the glass tube with a length of rubber tubing (Fig. 13). Fill the pump and the tubes with water. Then put a little pressure on the pump and the wax piston will rise. Experiment to see what weights can be lifted in this way.

HYDRAULIC BRAKES

Hydraulic pressure is used not only to do work but also to stop work. Most modern cars use oil in pipes to send pressure from the driver to the brakes on the wheels. In older cars, when the driver pressed the brake-lever with his foot, the movement was carried to the wheels by steel rods and wire ropes. These were not very satisfactory. In modern cars, the brake lever acts on a 'master' piston which presses on a liquid in a long tube. At the far end, near the brake, the liquid presses another piston (the 'slave'). The 'slave' piston puts pressure on the brake and the car is made to stop. Ask a motor mechanic to let you see the workings of a hydraulic brake. He will show you the 'bleeding' point in the pipe. This is the place where any air bubbles in the liquid are made to come out.

Why is it essential to have only liquid and no air in the pipe?

FLOATING AND SINKING

You have already learned that liquids differ in density. This difference in density produces a difference in pressure. The following experiment will show that the greater the density of a liquid the greater its power of lifting a load.

If you have not already compared the density of fresh and salt water, weigh an empty beaker. With a measuring cylinder, measure 100 c.c. of fresh water into it. Weigh it and record the weight of the water. Throw away the water and put 100 c.c. of a saturated solution of common salt in water into the beaker. Weigh it again and record the weight of the salt water. Which is the denser, fresh or salt water?

Put a *very newly laid* egg into a bowl of fresh water. Then put the same egg into a saturated solution of common salt. What difference do you see in the behaviour of the egg?

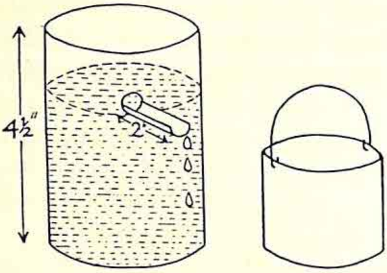

Fig. 14. Displacement can and bucket

So, salt water is denser than fresh water; it lifts the egg up and the egg floats in the denser liquid.

Now, half fill a tall cylinder with salt water and put the same newly laid egg into it. Add fresh water, very slowly, a little at a time, and stir the mixture well. A point will come when the egg will float at any level in the liquid. Can you say why this happens?

To find the answer to that question, lift out the egg and pour the liquid into a displacement can (Fig. 14) to the level of the spout.

Weigh a small can and put it beneath the spout. Put the egg into the liquid in the displacement can. Collect the liquid which falls into the small can. When the liquid has ceased to drip from the spout, weigh the small can again. What is the weight of liquid displaced by the egg? Dry the egg and weigh it. Compare the two weights.

You now know why the egg floats at any height in that liquid.

THE PRINCIPLE OF ARCHIMEDES

From the above experiment you know that *when a solid is placed in a liquid it is lifted up by a pressure equal to the weight of the liquid displaced.* This principle or truth was discovered by a learned Greek, Archimedes, in the third century before the birth of Christ; that is, over two thousand two hundred years ago.

You have also learned from that experiment that *the weight of a floating body is equal to the weight of liquid which it displaces.*

You have learned something about floating. Why do some substances sink in water? In fresh water the egg sank to the bottom and stayed there. Let us compare the weight of the egg in air with the weight of the volume of fresh water that it displaces.

Weigh the egg and record the result. Fill the displacement can with fresh water. Put the egg in the can and collect the water which flows from the spout. Weigh the water. Which is heavier, the egg or the water which it displaces? Why does the egg sink in fresh water?

Repeat the experiment with a stone, a one pound weight or with anything else which does not float.

Shape a piece of tin or aluminium foil into the form of a small boat. Float it in a bowl of water. Then press it together into a tight ball and put it in the water again. Why does it not float now?

Iron is nearly eight times as dense as water. Until 1818 ships were built of wood. How is that since that time, iron has been used for bigger and better ships?

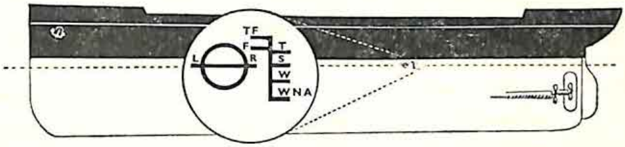

Fig. 15. The Plimsoll line

Take a cigarette tin. Put it on its side and allow water to enter. Does it float? Turn it open end up and try to push it into the bowl of water. Put some sand into the tin until it floats upright with about half its volume in the water. It is now a small iron 'ship'. Make a mark on the outer surface to note the depth at which it floats. Measure from that mark to the bottom of the tin. Measure the area of the bottom of the tin and calculate in c.c. the displacement of the 'ship'. Now dry the 'ship' and weigh it and its contents. What is the relation of the 'ship's' weight to the weight of the water which it displaced? Throw out the water and fill the bowl with a salt solution and again make a mark to show the depth at which the 'ship' floats.

Put more sand in the 'ship' until its rim is very near the surface of the water. Stir the water to make rough weather. Do you consider that it is safe to overload a ship? In the past, owners often overloaded their ships and sailors were drowned when they went down in storms. It was an Englishman, Samuel Plimsoll (1824-98), who suggested that a mark should be painted on the sides of all ships to show the point to which they may be safely loaded (Fig. 15). There are different safety levels on the Plimsoll mark for salt and fresh water and for stormy winter weather.

An unloaded ship floats high in the water. Every ton of cargo that is put into it displaces a ton of water. The ship sinks lower until it reaches the safety line. Then loading stops.

You have seen that liquids vary in their density. For many purposes it is necessary to have an instrument which will rapidly measure density. *The hydrometer* is that instrument. It is a glass tube weighted at one end to make it float upright. It floats lower in a liquid of low density than it would in one of high density. So the scale readings are high at the bottom and decrease upwards.

Hydrometers are used by the dairy workers in West Africa who buy milk from the Fulani women for butter making. Cows' milk is about 20 per cent. denser than water. If water has been added to milk, the hydrometer sinks below the milk mark and the attempt to cheat the buyers is discovered.

Hydrometers are used by careful car owners in hot climates. They use them every week to test the state of the acid in the car battery. When a battery is fully charged the density of the acid is about $1\frac{1}{4}$ times that of water. The little hydrometer in the testing pipette (Fig. 16) rides high in the sample of the acid sucked out of the battery for testing. If the charge in the battery is low, the density of the acid decreases and the hydrometer sinks in the liquid. Ask a motor mechanic to show you how he tests battery acid with a hydrometer.

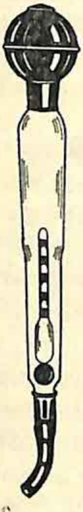
Fig. 16.

You can make a hydrometer with a plastic drinking straw about 20 cm. long. Close one end with wax. Put a ball bearing or some sand into it to make it float upright with about half its length in water. Tie a piece of black thread around it which can be moved up and down as a marker. Put the straw into a cylinder of water and mark the level at which it floats. Take it out of the water and measure the distance from the bottom of the straw to the mark.

Float the straw in other liquids: milk, salt water, kerosene, palm oil, etc. In each test, move the black cotton to mark the level at which the hydrometer floats. Then measure from the bottom of the straw to the mark. Note which substances are denser or less dense than water.

SURFACE TENSION AND CAPILLARITY

If you throw some drops of water on to a polished table or banana leaf, the water does not spread out and wet the whole surface. Instead, the drops form into little balls, and look as if they were covered with a thin skin. In a pond, mosquito larvae hang upside down from the surface, insects called Water Skaters run about over it; while little groups of Whirligig beetles perform an endless dance on it without wetting their feet.

The water surface seems to have a skin for the very small particles (the molecules) of which it is made are held together very firmly by a force called surface tension. In the following experiments you will see how strong this tension is.

(i) *The floating needle*. Polish a small needle by rubbing it in sandpaper or sandstone. After rubbing it do not touch it with your fingers. Lift it on a piece of tissue paper about the size of two postage stamps. Place the paper and the needle on the surface of a bowl of clean water. The paper will sink. What happens to the needle? Look carefully at the surface of the water around the needle.

(ii) *Pennies and pins*. Polish the top edge of a glass tumbler with a dry clean cloth. Place the tumbler on a saucer and pour water into it until it is full. How many pennies can you put into the glass without spilling any water? Drop them in very carefully and you will see the surface rise until it is above the level of the glass. You will be surprised how many pennies can be put into the glass before the surface 'skin' breaks.

If pins are used instead of pennies in this experiment the result is even more surprising.

REDUCING SURFACE TENSION

For various reasons, it is often necessary to reduce the surface tension of water. Put some drops of water on a piece of polished glass. Near them put some more drops of water to which some Teepol or other soapless detergent has been added. Note the behaviour of the drops in each group.

To protect fruit trees and other crops from insect pests, they are sometimes sprayed with chemicals. If these are in solution with water, the spray may form drops and the leaves will not be well covered by the insect killing liquid. As you have seen detergents reduce surface tension very successfully. So most sprays are mixed with a detergent to spread the liquid evenly over the whole surface of the plant.

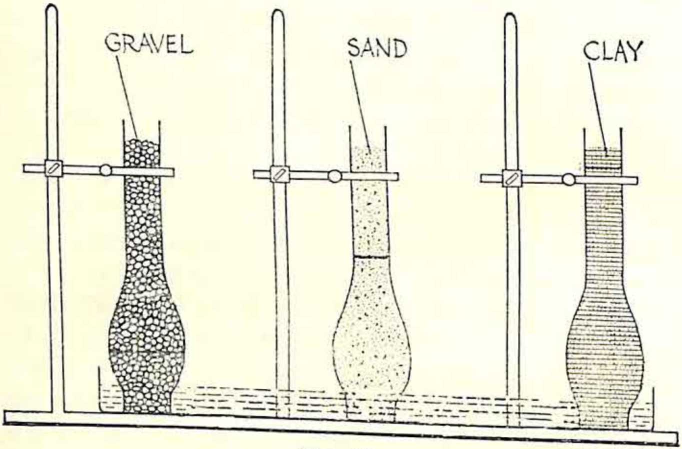

Fig. 17.

CAPILLARITY: HOW LIQUIDS RISE

You learned in Book 1, Ch. 5, that plants take in moisture from the soil and that it travels up through the plant. How does this happen? How does moisture rise in the soil? Why does it not all drain away quickly and leave the plants without water? Take three long lamp glasses. Put a little cotton wool in the bottom of each. Then fill the first with some well powdered red laterite and small stones, in the second put good black earth and fill the third with potters' clay, well dried and powdered. Stand them together in a tray of water (Fig. 17). Record what happens in each glass. How can you explain what you see?

This experiment may help you to understand how trees such as the Locust Bean are able to produce a great weight of new green leaves at the end of a long dry season and before a drop of rain has fallen.

Place a new brick or a new earthen pot in a bowl with about an inch of water in the bottom. After half an hour note how far the water has risen in the brick or in the side of the pot. Similarly, test a piece of new lampwick with its lower end standing in coloured water.

Take two pieces of sheet glass about 5 in. square. Wash them and polish them with a dry clean cloth. Hold the two sheets together, and a match between them, with a rubber band (Fig. 18). Stand the two sheets, with the match upright, on a tray, in a quarter inch of coloured water. Note what happens to the coloured water.

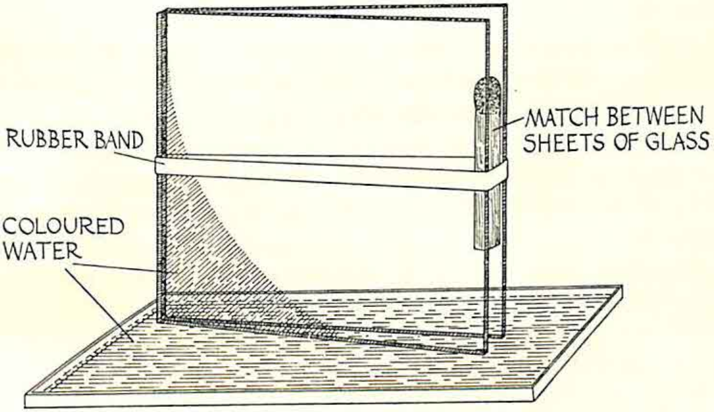

Fig. 18. Water rising between two sheets of glass

From these experiments you will have seen that water is drawn up in narrow spaces. The narrower the space the higher it rises. This ability of a liquid to pull itself up a narrow space is called capillarity from a Latin word meaning 'a hair'.

DO SOME SOILS HOLD MORE WATER THAN OTHERS?

Dry some sandy soil and some clay soil in the sun. Put 250 grams of dry sandy soil into a funnel standing in a 100 c.c. measuring jar. Put a small piece of cotton wool in the bottom of the funnel. Very slowly pour 50 c.c. of water on to the soil. When no more water drips through, measure the water in the jar. How much water has been held by the soil? Calculate the amount of water which would be held by 100 grams of that sandy soil. Repeat the experiment using an equal amount of dry clay soil. Which soil holds more water?

It is very important for plant growth in dry weather that roots should be able to reach soil which holds water. It is clear that water will drain away quickly from a sandy soil which is not able to hold it and that such a soil will only be suitable for plant growth in the rains. Clay soils, on the other hand, may be too wet for some plants in the rains when they often hold so much water that air is driven out (see p. 51).

SUMMARY

In this chapter you have learned something of the composition of water, about water as a solvent of both gases and solids and about substances which take in or give out water. You have also considered what happens when things are cooled by evaporation of water. You have studied the weight of water and its density, the pressure of water and its hydraulic power. You have seen a little of what causes things to float in water. Surface tension in water and capillarity in soil and their importance for plant and animal life have been noted.

THINGS TO DO

(1) Taste some distilled water and say why it differs from drinking water.

(2) Find out how a hydraulic car jack works. Compare the area of the hole through which oil is pumped with the area of the lifting piston.

(3) A test for water and water vapour: dip a piece of white blotting paper into pink cobalt chloride solution; dry it over a flame and note that the paper is blue. Now let a drop of water fall on the paper. It becomes pink again. You can use this as a test to see if an unknown liquid or gas contains water.

(4) Take a piece of dry (blue) cobalt chloride paper and leave it in the air. Notice how soon it turns pink. What does this change show?

(5) Breathe on a piece of this blue test paper. Does your breath contain water vapour?

(6) The speed of flow of river water may be measured at the centre and near the bank with stoppered bottles half filled with

water so that they float below the surface. Attach a piece of cork or light wood to act as a marker on the surface. Record the time of travel between pairs of marked places on the river banks.

QUESTIONS

(1) What is the difference between (i) an element, and (ii) a compound?

(2) One cu. ft. of water weighs $62\frac{1}{2}$ lbs. What is the pressure of water per square in. at bottom of a dam, one hundred feet deep?

(3) Why do you feel cold if you stand about in wet clothing?

(4) The very smallest tubes through which blood flows are called capillaries. Why?

(5) How can you get salt from sea water?

(6) What is the approximate weight of one gallon of water?

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CHAPTER 3

The Earth and its Neighbours

THE SURFACE OF THE EARTH

We know very little about how or when the Earth began. We know that it is very old—many millions of years old—and that there have been great changes on its surface. For thousands of years, wind and water have been at work weathering the older rocks; breaking them down and carrying them to the sea. There, the particles of rock settled and were gradually compressed by their own weight and became new rocks. The older rocks were very hard and because they seem to have been melted in some great fire they are called *igneous* rocks. The new rocks are softer and are called *sedimentary* rocks because they were formed as a sediment on the floor of the sea. Shake up some sand in a bottle and watch the sediment settle in the bottom.

Soil is the thin upper covering of some parts of the Earth's surface. There is no soil on bare rock. There is no soil at the bottom of the ocean. Soil contains rock particles, air, water, dead animal and vegetable matter and salts. It is also the home of many living things. Real soil differs from all the lower layers, the subsoil, beneath it because of the living things and the remains of living things in it. We speak of fertile soil and mean the top layer of real soil in contrast to the barren subsoils.

Real soil is made by the weathering of rocks, by the work of worms, termites and other small animals and by the activities of many kinds of bacteria (Book 1, p. 56). A very long time is needed to make even a shallow depth of real top soil: several thousand years. Yet, by bad farming and other forms of carelessness, this valuable material can be washed away by rain or blown away by wind in a few days. People sometimes think that this loss of soil does not matter. They say that, if it is lost in one place, there is plenty of good land elsewhere. That is not true. There is much barren mountain and desert land but the area covered by a workable depth of good farm and garden soil is very small.

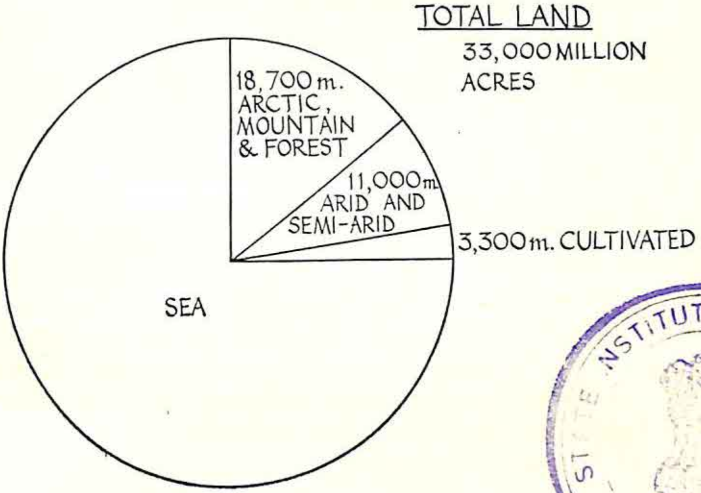

Fig. 1. Diagram showing the small area of cultivated land

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Soil is one of the Earth's most valuable materials: more valuable than gold. If all the gold and silver on Earth were suddenly destroyed, human life would go on. If all the good soil on the surface of the land were blown away we should all die very quickly.

The diagram (Fig. 1) on this page shows very clearly what a small part of the Earth's total surface is good farm land. Yet that small area has to feed more than two thousand five hundred million people.

Look at these recent United Nations figures showing the growth of the world population:—

Year	*Estimated total*
1900	1550 million
1925	1907 million
1950	2497 million
1975	3830 million
2000	6280 million

At present, more than two of every three people on this Earth do not get enough food daily to enable them to live a completely healthy and happy life; and the population increases by more than 13 million persons every year.

The urgent problem is to increase food production more rapidly than the population is growing so that all may have enough to eat.

SOME KINDS OF SOIL

Feel a piece of soil with your fingers. Look at it with a hand lens. Note its colour. The rocks from which a particular soil is made, the temperature and rainfall of the place in which it is found, the plant and animal populations which live on it, all help to make the soil in one place differ from the soils in other places. If your school has a farm, collect and compare samples of soil from several places in it.

Clay is the well known material from which pots are made. The particles of clay are very small; they hold water and do not allow it to pass through the soil. Clay is used in the centre of well-built earth dams. A clay soil is sticky and heavy to work in the rains; it becomes very hard and cracks in the dry season. If a sticky soil feels smooth when rubbed between the thumb and first finger it is probably a clay soil. If it is sticky but does not feel smooth, it is probably a silt.

A *silt* has particles which are larger than those in clay soils but which are smaller than those in sands. The River Niger (from the Latin word meaning black) was so called because of the great amount of dark brown silt carried down in its waters. The delta at the mouth of a large river is made of silt.

Put half a teaspoon of alum into a four gallon tin of water taken from a river in flood. Stir the water and alum well. Next day pour off the clear water from the top three-quarters of the tin and filter the remainder. Weigh the silt left on the filter paper.

Sands are soils made of rocky particles which are bigger and heavier than those in silts and clays. Shake some sand in a tumbler of water and note the time the particles take to fall to the bottom. Sand particles measure up to 2 mm. in diameter. *Gravels* are soils which contain many small stones measuring up to 15 mm. diameter. If you find a soil which has small rounded stones in it, you are probably on land which, long ago, was a sea shore.

Loams are soils which contain a mixture of clays, silts and sands. If a gritty soil can be formed into a ball that holds together when dry it is probably a loam. If the ball breaks down when it dries, it is a sandy soil.

Humus is a dark brown, formless material. It has the power to hold sandy soils together and to make clay soils less sticky. It holds water.

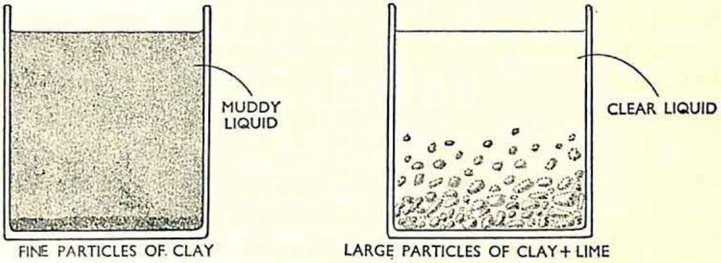

Fig. 2. Clay and lime combine

Leaves of trees and the bodies of dead animals decay to make humus. Garden and household rubbish, mixed with soil, urine, etc., in a compost heap become humus. Bacteria (Book 1, p. 56) in the soil cause the rubbish to rot down if the heap is kept damp but not too wet.

Here are some experiments which you may do with clay soils:

(i) Mix a little clay soil in water. Stir well and pour it into two glass cylinders (Fig. 2). Leave them for an hour. What do you see?

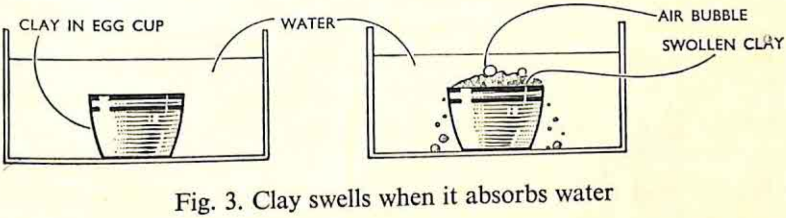

Fig. 3. Clay swells when it absorbs water

Add a teaspoonful of slaked lime to the liquid in one cylinder. Stir it and again let it settle. What happens to the clay suspended in the water? Compare it with the liquid in the other cylinder. Then filter the liquid in the other cylinder. Does the soil suspended in the water pass through a filter paper?

(ii) Fill a small cup with some *dry* powdered clay and level the top of the powder with a ruler. Carefully place the cup in a bowl of water (Fig. 3). Watch what happens. In that experiment you will have seen that dry particles of clay swell when they become wet. When clay particles in the soil swell they drive air out of it. Is clay, therefore, a good soil for growing plants? The next experiment will help you to answer that question.

(iii) Take some bean seeds and plant some of them in pots of clay soil and others in pots of sandy soil. Give equal amounts of water to the pots for a fortnight. Then stand the pots in water and carefully wash the soil away from each plant without damaging the roots. Compare the growth of roots in sandy and clay soils.

(iv) When the powdered clay was put into water it became soft and sticky again. Let us see whether that is always so. Heat some powdered clay very strongly for ten minutes over a flame. When it is cool note the change in colour of the clay. Put some of it in water. Does it still become soft and sticky?

(v) Take a lamp glass and fill the lower third with clay well pressed down. Fill the upper two thirds with water. Does the water pass through the clay?

LOOKING AT SOIL

You can lift some top soil and look at it in its natural state in the following way. Cut out the top and bottom of a large

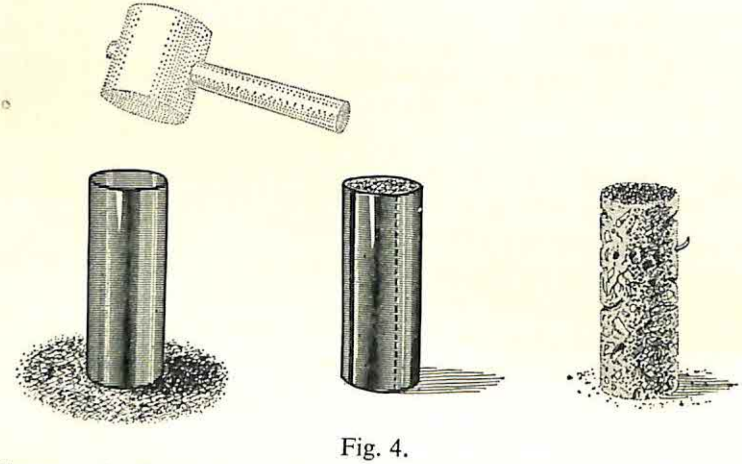

Fig. 4.

Hammer the tin into the soil

Dig it out and cut the tin with snips

Notice the large air spaces. What else can you see?

food can. After rain, place a flat piece of wood on the top of the can and hammer it into the soil. Dig the can out and carefully cut one side of it with metal snips. You should thus get an unbroken block of soil (Fig. 4). Write down all the things you see in it. Note the large air spaces.

Then crumble some of the soil and stir it up with water in a glass cylinder. Leave the soil for a day to settle and note what happens. What do you see floating on top of the water? Make a sketch showing the various levels of material at the bottom of the cylinder.

How much water is there in soil? Weigh a cigarette tin lid. Put some soil on the lid and weigh it again to find the weight of the soil. Then put the lid and soil out in strong sun until the soil is dry. Bring the tin in and, when it is cool, weigh it again. How can you explain the difference in weight? (Remember that some soils hold more water than others and that all soils are wetter in the rains than in the dry season.)

How much humus is there in the soil which you dug up? Again, weigh some of the dry soil in the tin lid. Heat it over a strong flame until the tin and soil are almost red hot. This will burn the humus in the soil. Let the tin cool and again weigh the soil. Is there any change in weight?

SOIL TEMPERATURES

Do soil temperatures vary with the seasons? Do soil temperatures vary with the depth of soil? Does the colour of soil affect its temperature? To answer these and other questions about soil temperature you will need a centigrade thermometer and a 6 in. wire nail. With a file make a clear mark one inch from the point of the nail. Make other marks at intervals of one inch up the nail.

(i) At a marked place in the school garden make a hole 1 in. deep using the marked nail and place the bulb of your thermometer in the hole for ten minutes. Shade the thermometer during that time. Record the temperature and repeat the observations at the same time of day and on one day every week throughout the year.

(ii) Next push the nail into the soil to a depth of 3 ins. and leave the thermometer in the hole for ten minutes. Again record the temperature. Finally, push the nail into the soil to its full depth of 6 ins. and test the temperature in the same way. Compare the three temperature readings.

(iii) Obtain soil temperatures on dull and sunny days; on days when the soil is very wet and when it is very dry. Measure the temperatures of black soils and red soils at the same time of day. Measure soil temperatures at night. What do you learn from these readings? Compare them with the readings of air temperatures taken in the shade at the same times.

SALTS IN THE SOIL

You already know at least two salts: common salt used in cooking food and Epsom salts. Chemists know many others. You have learned how to dissolve mineral salts* out of the soil and you also know that such salts are needed for healthy plant growth. Some of these salts come from the breakdown of the rocks and others from the rotting of vegetable and animal remains in the soil. Foodcrops use up large amounts of these valuable salts. When we take crops from our farms and use them for food the salts do not get back into the soil. So they must be replaced by putting compost, animal manure and 'artificial fertilizers' on the land. 'Artificials' are carefully prepared mixtures of the salts which chemists have found in the soil. In some countries the government assists farmers to buy the needed fertilizers. For it is clear that they cannot go on taking bananas, palm oil, cocoa, groundnuts from the land and exporting thousands of tons of them without putting something back into the soil.

Plants cannot be healthy if they lack any one of the salts necessary for proper growth. You may notice, for example, that some of the leaves of an orange tree have yellow patches on them instead of being a healthy dark green. This may be due to a lack in the soil of a mineral salt containing magnesium.

An ounce of Epsom salts (Magnesium sulphate) may be dissolved in four gallons of water and poured on the soil around the tree. Some gardeners use dried blood and powdered burned bones as fertilizers because they rot down slowly and supply plants with the needed salts over a period of several months.

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* (Book 1, p. 82). Note: A *mineral* is a substance found in the soil. Digging out some of the substances found in the soil is called *mining*.

LEACHING OF SOIL

Heavy rains wash the needed salts out of the soil. This is called leaching. You can test the leaching of soil. Place an enamel basin in a hole in the ground at a place where rain water runs off from the school farm or garden. Filter and evaporate the water to discover whether it contains any dissolved salts. This experiment may show you how necessary it is to reduce the flow of rain water off farm land as much as possible.

The heavy tropical rains leach lime and other minerals out of the upper layers of the soil. This washing out of the dissolved mineral salts produces the common red *laterite* soils of the tropics from which almost everything has gone except some iron and aluminium compounds.

SOIL EROSION

Plants need soil and very successfully hold it. Plants protect soil from the wind and rain. They prevent them from blowing and washing the soil down to the sea. Men on the other hand cut down trees and often leave the soil without any plant covering with the result that in many places it has been washed and blown away.

Go out to a neighbouring farm and note some place where much water runs off the land when rain is falling. At the point where the waterway leaves the farm dig a hole. Place a 4-gallon tin in it so that rain water running off the farm will flow into the tin. Then, while it is raining, note the time the run-off water takes to fill the tin. Bring the tin in and allow the water to settle. Then pour off some of it carefully and filter the rest. Dry the soil found on the filter paper and weigh it to learn how much soil was carried off the farm at that place and in that time.

From the school rain records find the amount of rain which has fallen in that time. So, when x inches of rain fell y lbs. of soil were removed from that farm. Then, from your knowledge of the total average rainfall for the year you may calculate how much soil will be carried away from that farm by that run off in one year.

If you still doubt the serious loss of soil which is caused by rain erosion, go outside and look at the walls of your school or of your home. You will probably see that the ground level around them is clearly some two or three inches lower than when the walls were built. Go into the market and look at some of the shade trees which were planted there. In many cases you will see that they are standing on small mounds of earth, two or three feet high. The roots of the trees have held some soil together, while the bare earth between them has been worn and washed away in the lifetime of the trees.

In some parts of Africa there are many hills with long flat tops. The flat tops were part of a level plain. Now the ground between them has been eroded away and its level has fallen by several hundred feet.

Metals, mineral oils and carbon compounds are all obtained from the rocky crust of the Earth on which you live. Railway engines, motor cars, aeroplanes—even your pen nibs and the lead in your pencils—are made of such materials which may have been dug out of the ground only a few months ago. The rocks of the earth are the source both of the soils from which men grow their food and of the metals from which they make tools to lighten their work. Copper, tin and iron are metals, and all metals are elements. They are pure substances. Make a list of all the metals you know and of the common uses of each of them. Why are the metals used for these purposes?

An alloy is a mixture of two or more metals. Bronze, brass and solder are alloys. Metals are melted and mixed together to make alloys which are lighter or stronger than pure metals. Very few metals are used in their pure form.

There are certain ways in which metals differ from other things such as wood, glass and rubber. Try to find some of these ways and make a list of them. For example, hammer a piece of copper wire. It will become a flat strip. Test other metals to see whether they can be beaten in this way.

Twist two feet of copper wire once round a smooth iron rod. Hold the two ends of the wire with pliers and pull first one end and then the other end, ten times. Then measure the copper wire again. What has happened to it? See whether you get a similar result with iron wire.

Rub some copper or iron wire and some pieces of silver and aluminium with talcum powder and kerosene. What does the rubbing do to these metals? Test whether you get a similar result with other metals.

In many villages, the teacher strikes a large piece of iron to call the children to school. The iron gives out a loud ringing sound. What other metals can be used, for example in church bells, in this way?

The commonest use of copper is to carry electricity because, after silver, it is the best metal for that purpose. We say that copper is a good conductor. All metals are conductors of electricity. You will learn in Chapter 5 that they are also conductors of heat.

Some metals can be joined together by welding. Ask a blacksmith to show you how two pieces of iron can be welded: that is, joined by heating them strongly and then hammering them together.

Heat some lead in an iron pan and pour it into a cigarette tin lid. This is called casting metal. When it is cool, knock the lead out of the tin. You will see that it has taken the form of the lid. Some smiths in West Africa are very skilled in casting brass and aluminium in clay moulds. Look for examples of cast iron and the casting of other metals in the various parts of motor car engines and elsewhere.

You will have seen that while metals differ in many ways from other substances such as wood and rubber, they also differ among themselves. We cannot even say that all metals are solids, for the densest metal, Mercury, is a liquid.

IRON AND STEEL

Iron is a grey, magnetic metal which is obtained from iron ore by burning it with charcoal or coke. Perhaps you have hills where the heavy iron stone was mined. Perhaps in your neighbourhood you may know of an old furnace where blacksmiths used to burn stone to make iron.

Now, iron is produced in large blast furnaces (Fig. 5). The furnace is filled from the top with a mixture of iron ore and coke which are burned together with a blast of hot air. The iron ore contains an oxide of iron. Carbon from the coke joins with the oxygen in the ore and the iron is set free. The resulting 'pig' or cast iron contains up to 4.5 per cent. of carbon and is easily broken. It is used for casting such things as the cylinder blocks of petrol and diesel engines.

Long ago men learned how to make iron stronger by heating it and beating it, changing it into steel. *Steel* is iron containing from 0.1 per cent. to 1.5 per cent. carbon. Nowadays, much steel is made by blowing oxygen through the hot, liquid pig iron to remove most of the carbon.

There are many grades of steel. Many of the things which we call 'iron' such as the 'galvanised iron' used for roofing is a grade of sheet steel. Most of the iron used in building ships and houses is in the form of mild steel. It is strong and can be forged (that is it can be heated and hammered to any desired shape). It can be machined but it cannot be hardened. Therefore it cannot be used for sharp tools, such as chisels and saws. For these, special steels are used which can be softened and hardened as required.

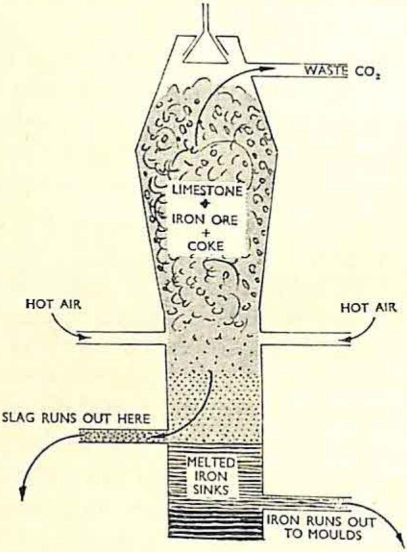


Fig. 5. A blast furnace

Take any worn-out steel file. Can you cut the file with a saw? Put the file into a fire and heat it until it is a dull red all over. Cover it with dry sand and leave it to cool slowly. You will probably find that you can now cut it.

Now put it back into a forge. Heat it to a bright red, plunge it quickly into a bucket of clean, cold water. When it is cool, try again to cut the steel with the hacksaw.

MINERAL OILS

Mineral oils are substances in which (as in coal) the energy of the sun has been stored for millions of years. The oils are found in layers of shale (a rock, like very soft slate) deep down in the Earth's surface. They may have been formed by the decay of vast numbers of plants and animals. Now, the shale is like a large sponge, holding millions of tons of oil. A hole is drilled down to the shale; then the weight of rock above and the pressure of underground gas forces the oil up through the hole (Fig. 6). It comes to the surface as a thick, black liquid and is pumped to a refinery. There it is heated and petrol, kerosene, motor oil and grease, paraffin wax and benzine are obtained from it. When these substances are burned some of the long stored up energy of the sun is set free.

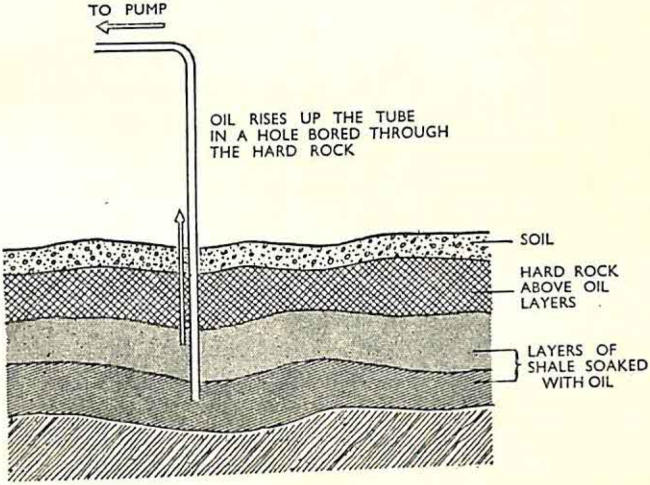

TO PUMP
OIL RISES UP THE TUBE IN A HOLE BORED THROUGH THE HARD ROCK
SOIL
HARD ROCK ABOVE OIL LAYERS
LAYERS OF SHALE SOAKED WITH OIL

Fig. 6.

CHALK, LIMESTONE AND MARBLE are three forms of one of the most important compounds used by men; calcium carbonate. In many places (chiefly in the south of England and in America) there are very thick layers of white chalk rock. It is natural calcium carbonate and was formed long ago from millions and millions of the shells of very small sea animals (Fig. 7). Coral, sea shells, snail shells and the shells of birds' eggs are also natural forms of calcium carbonate.

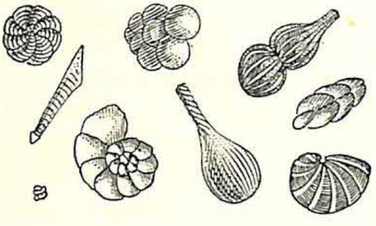


Fig. 7. Some of the tiny shells which make up chalk (seen under microscope)

Examine some calcium carbonate. Then:

(i) Describe its appearance. Look at it with a hand lens. Can you mark it or cut it with a knife?

(ii) Powder some of it and test to see whether it is soluble in water.

(iii) Is calcium carbonate soluble in dilute acid? Into a clean test tube put a quarter inch of the powder. Cover it with dilute hydrochloric acid. What do you see?

(iv) Take two clean test tubes. Half fill one with clear lime water. Put calcium carbonate powder and dilute hydrochloric acid in the other tube as in the last experiment. Hold the test tubes as shown in Fig. 8. The bubbling (called effervescence) which you saw shows that a gas is being given off by the action of the acid on the compound. Name this gas.

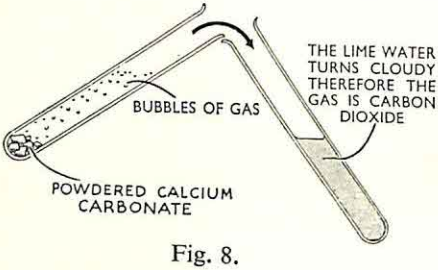

THE LIME WATER TURNS CLOUDY THEREFORE THE GAS IS CARBON DIOXIDE
BUBBLES OF GAS
POWDERED CALCIUM CARBONATE

Fig. 8.

(v) Does heat change calcium carbonate? Take two cigarette tin lids and on each place a small heap of powdered calcium carbonate. Heat one strongly with a blow lamp or hot Bunsen flame as in Fig. 9 until it glows. Continue heating it for five minutes. Then leave the powder until it is cold. Is the material in the tin still calcium carbonate? Add *one* drop of water to the powder. What do you notice? Add two more drops. Feel the tin with your hand. (Be very careful not to add too much water.)

Now, add three drops of water to the tin which was not heated. Does anything happen?

It seems that the calcium carbonate in the first tin was changed by heat. What happened during the change? Do the following experiment to find the answer to that question.

(vi) Put a small amount of powdered calcium carbonate in an ignition tube and some lime water into a small test tube. Heat the tube containing calcium carbonate and hold the test tube close to it as in Fig. 8. Shake the lime water. What do you see?

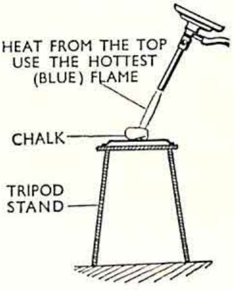


Fig. 9.

These experiments show that calcium carbonate is changed by heat into calcium oxide (quicklime) and that carbon dioxide is given off. The lime which is sold in tins for making whitewash is quicklime. When you added water to the quicklime, the two substances combined to form slaked lime: calcium oxide +water becomes calcium hydroxide.

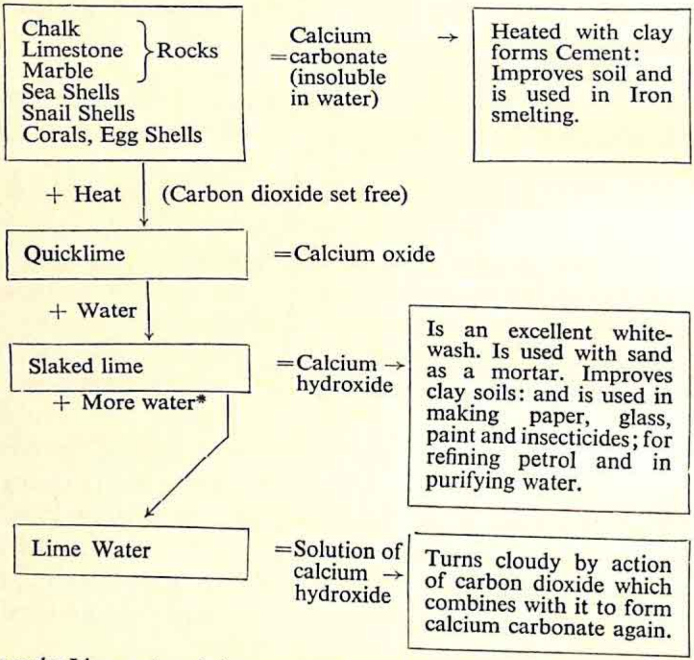
Note: sticks of blackboard chalk are *not* made of calcium carbonate: they cannot be used in the above experiments; for blackboard chalk is calcium sulphate, a different compound.

Quicklime has been used by men from very early times. It was probably the first material used to increase soil fertility and it is certainly one of the oldest building materials known. *Cement* is made from limestone and clay heated together and ground to a fine powder. *Slaked lime* mixed with sand is used as a mortar in building. It hardens in combination with carbon dioxide from the air.

Lime plaster, still in good condition, has been found in some of the pyramids built in Egypt more than 4,500 years ago. The Greeks, Romans and Moors used it in the countries around the Mediterranean Sea before 350 BC.

At the present time no other substance is used in such large quantities and for so many purposes as calcium carbonate and the substances obtained from it.

SOME OF THE USES OF CALCIUM CARBONATE



Heated with clay forms Cement: Improves soil and is used in Iron smelting.

Is an excellent whitewash. Is used with sand as a mortar. Improves clay soils: and is used in making paper, glass, paint and insecticides; for refining petrol and in purifying water.

Turns cloudy by action of carbon dioxide which combines with it to form calcium carbonate again.

*To make Lime water, shake up some slaked lime with some water in a bottle or flask. Let it settle and then pour off the clear liquid and store it in a well corked bottle.

THE ATMOSPHERE is rather like a blanker of gas wrapped around the Earth. There could be no living things and the whole surface of the Earth would be very different if there were no atmosphere. For, as you already know, living things need oxygen; and, without oxygen and the other gases of the atmosphere, the surface would be a barren desert like the Moon. The atmosphere is made up in part of gases which have been set free from the mineral substances of the Earth and in part, as you know, by the work of the green plants.

In Book 1, Chapter 3, you learned that air is a mixture of
The present composition of the air is:

Nitrogen	about 78%
Oxygen	,, 21%
Carbon dioxide	,, 0.03% and
Some water vapour and other gases	

The air is that part of the atmosphere in which we can live without difficulty. At the top of high mountains the density of the atmosphere is very small and we say that the air is rare or rarefied: meaning that there is not enough of it for most living things. There is sufficient air for life in only a small part of the atmosphere. Even a mile above sea level the air is too rare for most men to breathe.

Until recently it was believed that the atmosphere ended about twenty miles above the Earth's surface: that it became more and more rare and cold until at last there was nothing. The vast Space between the Earth and all the stars was thought to be quite empty: a vacuum, through which only light and heat waves could travel. At the present time, much is being learned from the rockets which are being sent out into Space and we know now that Space is not empty.

THE FORCE OF GRAVITY

You have learned in Book 1, Chapter 2, about the pressure of the air. What is it which causes this pressure? Why is the atmosphere dense near the surface and less dense at a distance from the Earth? Why does the atmosphere, which is a mixture of gases, not disappear like a puff of smoke?

The force which keeps the atmosphere from floating away is the same as that which causes a coconut to fall to the ground. You may kick a ball as high as you can but it will always return to the Earth as if pulled down by some unseen force. We know that large, heavy things pull more strongly than small things and that near things pull more than distant ones. The coconut falls to the ground because the Earth is large and near. The pull of the Earth is greater than the pull of the coconut. We call this unseen force by which all things are drawn towards each other, the Force of Gravity.

THE SUN AND ITS PLANETS

In Fig. 10 you will find some facts about the Earth and the other planets. To get an idea of the distance of the planets from

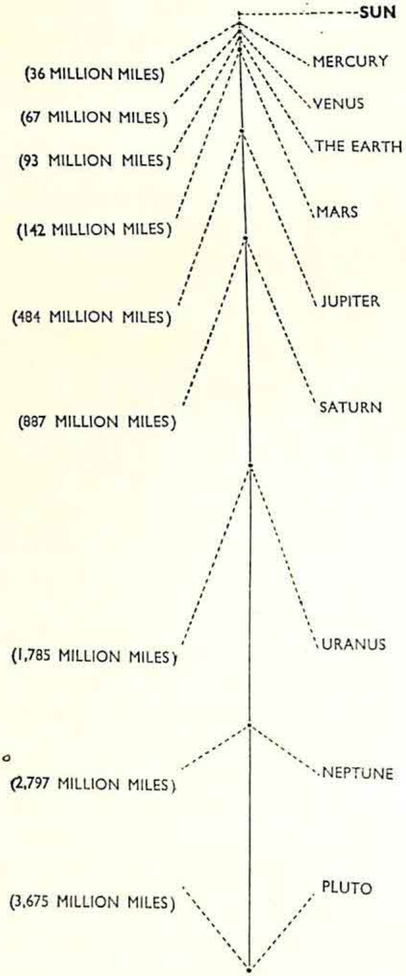


Fig. 10. The Sun and its planets: that is, the Solar System

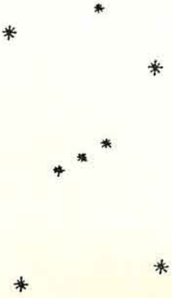


Fig. 11.

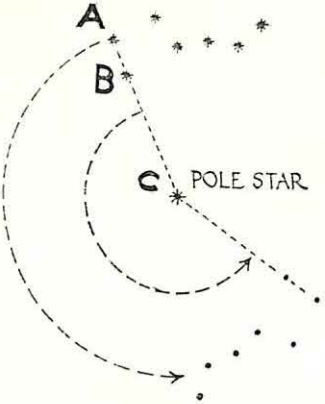


Fig. 12.

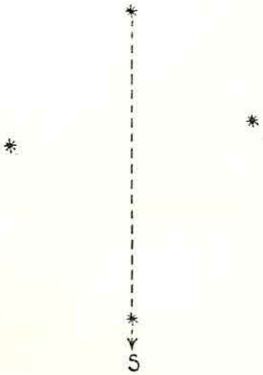


Fig. 13.

the Sun and from each other, put a football in the middle of a large field and suppose that it is the Sun. Thirty paces from it put a small steel ball bearing: that is the Earth. One hundred and fifty paces from the Sun put a table tennis ball: that is Jupiter, the largest planet. In the corner of the field, put another ball bearing: that is the planet Uranus. See how small and distant they are in the field. The furthest planet, Pluto, would be half a mile away.

When you look at the sky on a clear night you may see a star which is much brighter than all its neighbours; and which moves across the sky by itself and is not one of a group of stars. That star is one of the other planets circling round the Sun.

THE FIXED STARS

All the stars which you can see on a clear night, except the occasional planet, seem to be at fixed distances from each other and so we call them the Fixed Stars. They are suns like our Sun but are so far away that they seem to be smaller than the planets. The fixed stars form patterns in the sky such as those shown in Fig. 11. You should ask the elders in your homes to tell you the names given to such groups of stars by your fathers.

In the northern part of the sky you may be able to see a group of stars as in Fig. 12. The stars A and B are pointers to C, the Pole Star, which you can sometimes see if you live north of the Equator. If you then set up two sticks so that their tops are in line with A, you will be able to note, after half an hour or more, that the line ABC moves like the hour hand of a clock with its centre at C. In fact, if you are out at night you can tell the time by watching the pointers move around the Pole Star. When you look towards the Pole Star you are looking to the North.

If you look to the southern half of the night sky you may see a group of stars as in Fig. 13. This is the Southern Cross and the stars we have linked by a dotted line point to the South (but there is no definite South Pole star).

THE MILKY WAY

Go out again on a clear moonless night and look up at all the stars. Many of them stand alone in the deep blue of the sky; some of them however seem to be crowded together along a great path of glowing starlight, the Milky Way. About 1600 AD

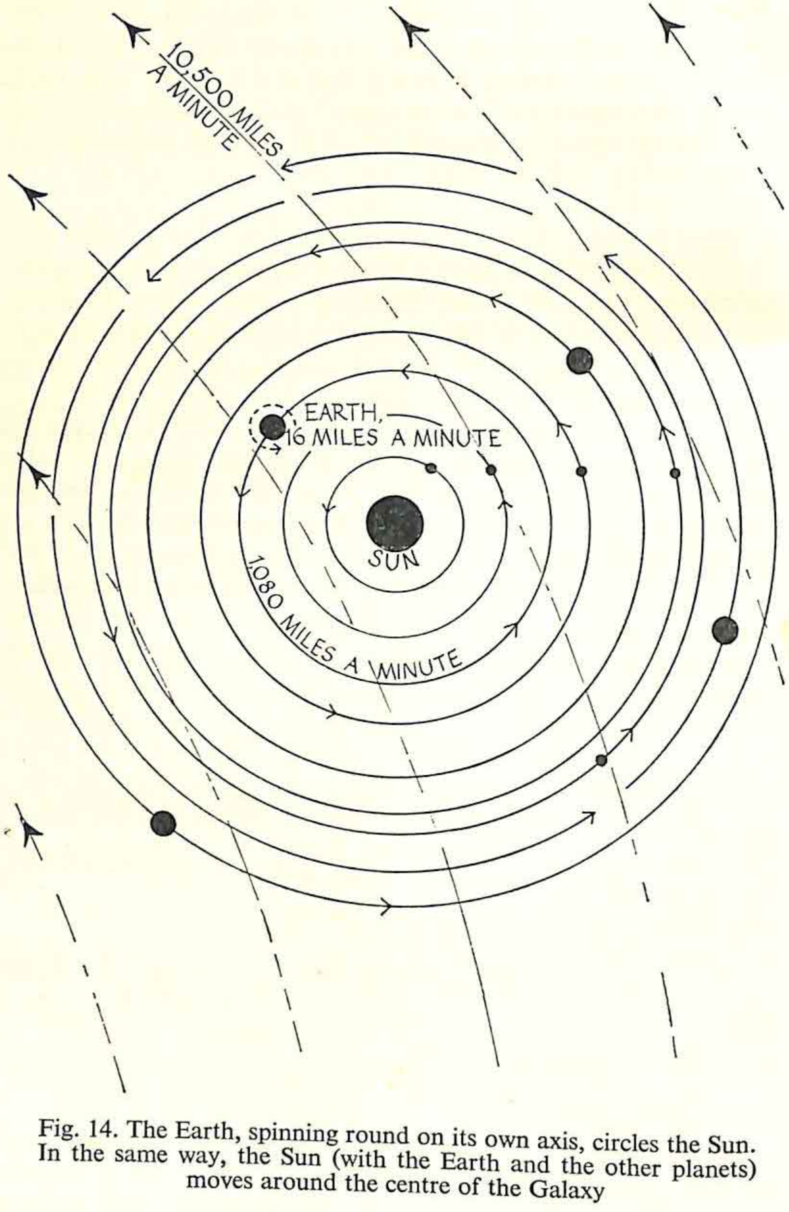


Fig. 14. The Earth, spinning round on its own axis, circles the Sun. In the same way, the Sun (with the Earth and the other planets) moves around the centre of the Galaxy

the men who studied the stars (astronomers) began to look at the Milky Way with new and bigger telescopes. They found that it is a great wheel made up of many millions of stars, each of which is a sun as big or bigger than our Sun and they saw that our Sun and its planets are only a very small part of this great wheel of stars which we now call a *Galaxy* (this was the Greek word for 'milky') (Fig. 14).

SUMMARY

In this chapter you have learned something about the soils of the Earth's surface. You have found that metals shine when they are rubbed; they can be beaten into sheets and pulled to make thin wire; they give out a ringing sound when struck and are good conductors of heat and electricity. They can be joined by welding and can be cast in moulds. You have learned about the uses of iron and steel and you know why metals are mixed to form alloys. You now know how mineral oil is obtained. You have done some experiments with calcium carbonate and learned of the ways in which this substance is useful. You went on to learn something about the atmosphere which surrounds the Earth, about the place of the Earth in the Solar System and about the place of the Sun in the Galaxy which we call the Milky Way.

THINGS TO DO

(1) Make a collection of samples of igneous and sedimentary rocks.

(2) From a well digger obtain samples of soils from all levels of a well.

(3) Look for a planet in the clear night sky.

(4) Cut out a piece of soil, about 9 ins. x 9 ins. x 6 ins. and place it in a basin. Keep it damp for several weeks and observe the growth and development of the plants in it. Watch for animals living among the plants. Name any you can see and record their activities.

QUESTIONS

(1) Name the useful substances obtained from the rocks of the Earth and say how each is used.

(2) What is an alloy? Why are alloys useful?
(3) How would you discover if a solid substance is a metal?
(4) What is the difference between iron and steel?
(5) What do you know about mineral oils?
(6) How do we use calcium carbonate?
(7) How much of the Earth's surface is covered by water?
(8) What is laterite?
(9) For what purpose would you use lime water?
(10) What causes a coconut to fall to the ground?
(11) How much nitrogen is there in the air?
(12) Why is it wasteful to use surface soil as a building material?

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CHAPTER 4

Finding Out about Animal Life

In Book 1, p. 73, you learned that animals are placed in groups. Scientists call this grouping, classification. When you have revised this work you will be ready to study the life histories of some of the animals around your home and school. It is no good just reading about animals. You must go out and watch them carefully and make notes immediately. This is *field study*. Some of the smaller animals may be brought into the classroom and kept for a time. They should be given a house or cage as nearly like their natural home as possible where they may be studied until it is time to set them free again.

SOME INVERTEBRATE ANIMALS

Charles Darwin calculated that, in England, there are between twenty-five and fifty thousand *Earth-worms* in an acre of soil. You might begin by finding out the worm population of your soil. Earth-worms can be made to come to the surface where you can collect them and count them, by pouring a dilute solution of potassium permanganate on the soil. Mark out a square yard. With scissors, cut and clear all the grass and other small plants within that area. Cover the soil with paper and leave it for a time so that worms which have been frightened may have time to return. Then pour a gallon of the solution (¼ oz. of the crystals per gallon) on to the cleared area. When the solution has had time to soak in, look for worms, pick them up gently with forceps and put them into a jar. When no more worms come up, count your catch. Compare the number of worms caught in different soils and the number caught in the same area on a cool day and a hot day.

Worms are found in the surface layers of all good soils; especially in those which contain much humus. If its skin dries a worm dies. So, when the surface is not wet, worms burrow down to moister layers. They avoid light and generally only come out and move about on the surface in search of food at night. Worms make their way through soil partly by force and partly by eating soil and passing it through their bodies. Darwin estimated that, in a year, 320 million tons of soil pass through the bodies of worms in England. (How many goods trains, made up of thirty-two trucks, each carrying ten tons of earth, would be needed to move all that soil?)

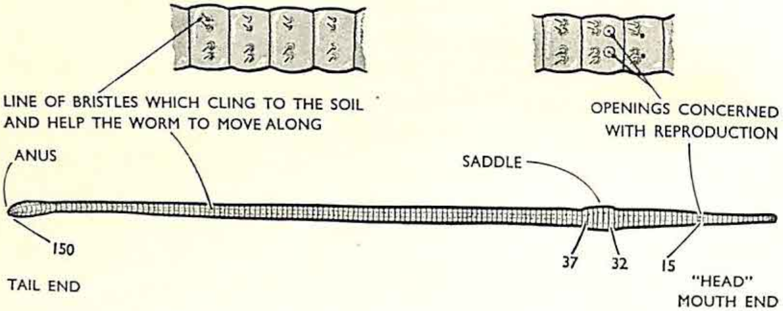
LINE OF BRISTLES WHICH CLING TO THE SOIL AND HELP THE WORM TO MOVE ALONG
OPENINGS CONCERNED WITH REPRODUCTION
ANUS
SADDLE
150
37
32
15
TAIL END
"HEAD" MOUTH END

Fig. 1. Underside of the earthworm (× ½)

Few people realise the immense amount of work done by earth-worms for farmers and gardeners. By their continual tunnelling, worms open up the soil for air and water. They bring up finely ground soil from a depth of one to two feet and push it out on to the surface. They also pull leaves down into their tunnels and this adds humus to the soil. In these various ways worms do much to improve the soil.

Put some worms in a wormery and, after they have settled down, watch their behaviour. Examine a worm carefully (Fig. 1). Look for the little bristles on its body which it uses when moving. Put the worm in a piece of rough brown paper and listen carefully when it begins to move. How does it move forward? Can it move as well on a piece of glass?

All earth-worms produce both eggs and sperm. During mating (Fig. 2) each worm passes sperm from its own body into storage pores in the body of the other worm. The worms separate. In some, a saddle produces a gummy ring which hardens as the worm wriggles backwards out of the ring. Eggs are placed in the ring together with sperm from the other worm and then the ends of the ring close up to form a cocoon. Inside this cocoon the fertilised eggs hatch and small worms appear.

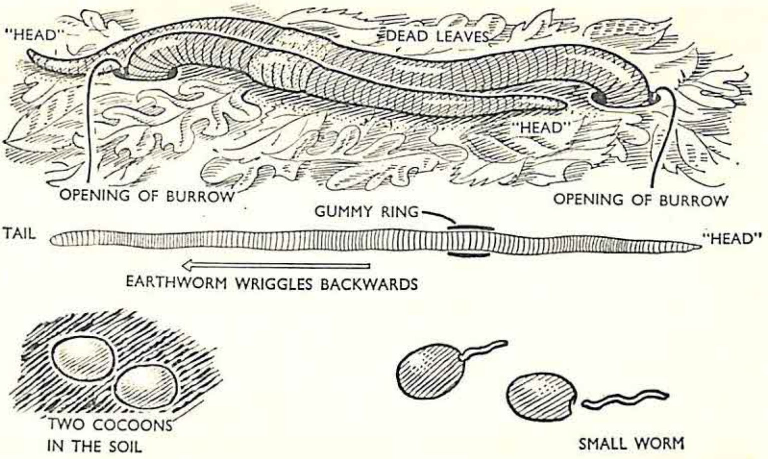

Fig. 2. How new earthworms are produced
(*Above*) Mating (x1); (*Centre*) Foaming the Cocoon (× ½)

Molluscs are invertebrates with soft bodies which are protected by a hard chalky shell. If you live in forest country you will know the large brown *Edible Snail* which is collected and sold in markets for food. As a mollusc grows it adds a little to the edge of its shell to make it bigger. Look at a large snail. You may get an idea of its age by counting the number of rough lines or ridges. If the snail is disturbed it draws itself into its shell. Try to find out as much as you can about its life history. What leaves does it eat? Where are the eggs laid? Put a snail on a piece of glass to see how it moves. Snails are called *Univalves* because they have only one shell (Fig. 3). The *Oyster*, which lives in the sea and in lagoon water fixed to a rock or to mangrove tree roots, is a *Bivalve* because it has two shells which are joined by a hinge. The snail goes in search of its food but the

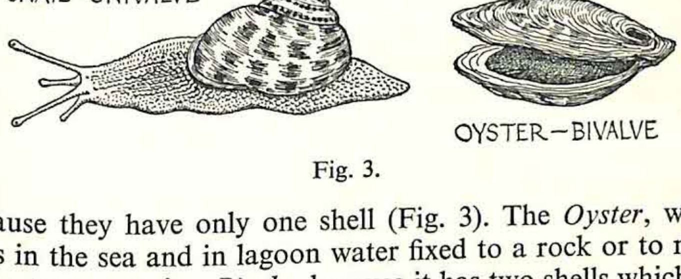

Fig. 3.

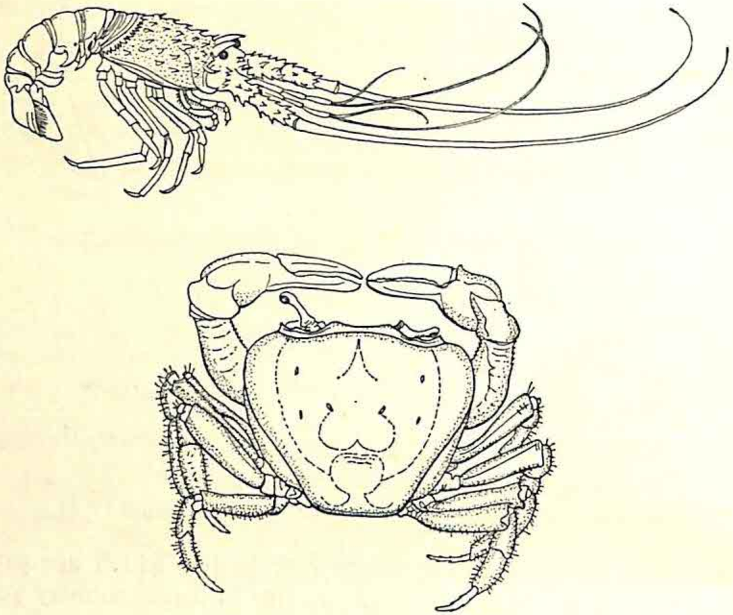

Fig. 4. Prawn (*top*) and crab

oyster lies in the same place finding its food in the water which flows between its two shells. If it is disturbed the two shells close together very tightly.

Crabs, *prawns* and *lobsters* (Fig. 4) are animals which are covered by a hard, jointed material rather like your finger and toe nails. The hard case protects them. In crabs, the head and chest are covered by a wide flat plate; in prawns and lobsters it is curved around the side of the chest. Some crabs breathe in water by means of gills on their legs but others can also use gills to breathe in air. Look for the large reddish black *Mangrove Crab* found in swampy salt marshes, the *Fiddler Crab* with one of its claws much larger than the other, which you can see running about on the sea shore, and the *Hermit Crab* which lives in an empty whelk shell.

Look for small crabs under rocks on the sea shore and keep them in an aquarium. They moult (that is, break out of their hard covering) about fourteen times before they become fully grown. If a young crab loses a leg it gets a new one when it moults.

These hard-backed animals feed on all the refuse on the sea shore. They are good to eat but should not be used for food if they have been near sewage.

Many people wrongly think that *Spiders* are insects. Count a spider's legs and then count those of a house fly or a grasshopper. An insect has a pair of antennae on its head: does a spider have them? Fully grown insects have bodies which are divided into three main parts: how many are there in a spider's body? Note that the spider has jointed legs and no wings. With your hand lens count the number of a spider's eyes. (Fig. 5).

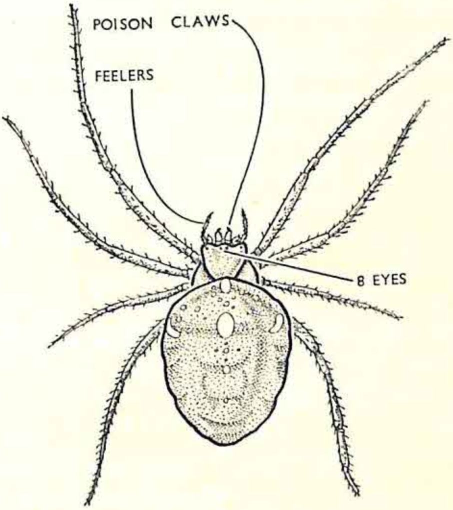

Fig. 5. The web spider

Watch different kinds of spiders at work spinning webs. Sketch the different kinds of web and note the animals killed by each kind of spider. Then you can say whether spiders are useful to man. With a hand lens, look for the spinnarets, on the abdomen of a spider, from which the thread emerges. Watch a spider making its web. Is the web sticky all over? By observing spiders, discover if it is true that the female cares for her young but eats her husband as soon as they have paired.

Look for a *Scorpion* under a large stone or in an old termites' nest. Keep several in a large cage and study their behaviour. You will have to provide them with regular meals of spiders and insects. Count the number of legs and the number of joints on the legs. Note, in your cage, whether the scorpion produces eggs or living young. How does the female scorpion carry her young?

Although *Insects* are only one group among all the invertebrate animals, they include ten times as many different kinds of animals as there are in the whole vertebrate division. Even now, we protect ourselves and our food stores from insect attack with difficulty. What will happen when these uncountable millions of insects develop still further? Clearly, it is necessary to study them.

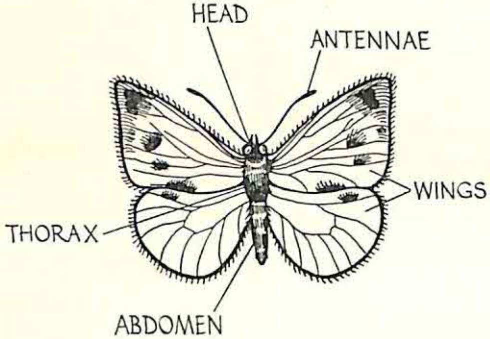

Fig. 6. An insect

Note the following facts about insects. (Do not expect to find all of them in every insect you study.)

(i) There is no backbone but the segmented (jointed) body has a horny covering.

(ii) The body is divided into a head, a thorax (or chest) and an abdomen (Fig. 6).

(iii) There are no lungs for breathing. Air enters the sides of the insect's body through holes called spiracles. Each hole leads into a breathing tube (trachea) which divides into smaller and smaller tubes which take air to all parts of the insect's body. In many insects, the head has a pair of antennae and a pair of compound eyes. Look at the mouth parts with a hand lens. In some insects they are used for sucking: in others, for biting and in others for piercing food.

(iv) The thorax has three segments, each having a pair of jointed legs; the second and third segments may each have a pair of wings. (Some flies, e.g. the house flies, have only one pair of wings.)

(v) There is often a change of form during growth.

(vi) The blood is not red.

In most animals, the young are very like their parents. They grow little by little and change gradually. In the insects, however, the young forms and the adult insects are often quite different in appearance: they move and feed in different ways. Many young insects become fully grown only after several changes in form and habits.

The egg of a butterfly, for example, hatches into a *larva*. The larva feeds hungrily; it grows and later changes into a *pupa*. The adult insect (the imago or the complete butterfly) is formed inside the pupal covering.

This series of three changes during the life history is called a complete change. Bees, wasps, beetles and flies have this sort of life history. Cockroaches, grasshoppers, termites and bugs have no pupal stage and are said to have an incomplete change. Look at this table:—

Insect examples	*Some names used in describing the life history of Insects*			
	Egg	*Larva (feeding stage)*	*Pupa (resting stage)*	*Imago (adult stage)*
Butterfly	Egg	Caterpillar	Chrysalis	Imago
Bee Wasp	Egg	Grub	Pupa	Imago
House-fly	Egg	Maggot	Pupa	Imago
Cockroach Grasshopper Termite Dragon-fly Bug	Egg	Nymph		Imago

The main difference between a nymph and the adult insect is that the former has no wings.

SOME INSECTS TO STUDY

Keep a few *cockroaches* in an insect cage. Feed them on sweet and starchy food. Note that they will also eat paper, cloth, leather and other household goods and therefore are very harmful.

Keep *grasshoppers* in a cage with soft sandy soil and give them fresh green grass daily. Watch a male grasshopper rubbing its hind legs on its wing case to make the well-known 'ZZT', 'ZZT', 'ZZT' which is its way of calling the female. Notice how the female lays eggs in the soil and watch the development of the young nymphs. Compare the movement of the young with that of the adults. Locusts are a species of grasshopper which sometimes swarms in large numbers. When they do this the number of locusts in one square mile may be many times more than the number of men and women in the whole Earth.

Keep one adult *mantis* in a cage planted with grass—and give it moths to eat. If you should catch a female which has been fertilized, she lay may eggs in small cases fixed to a piece of grass or small stick. Watch the eggs hatching.

BUTTERFLIES AND MOTHS

Look on the under side of the leaves of citrus trees for some very small white balls. These may be the eggs of the citrus swallowtail butterfly. Put a twig, which has some of these eggs on one of its leaves, into an insect cage and wait for the eggs to hatch. A very small caterpillar will come out and start eating the leaf. As it eats it will grow until it has to stop to throw off its skin and grow a new and larger one. This is called moulting. (Many birds lose some feathers at the end of a breeding season and grow new ones: this also is called 'moulting'.) The caterpillar moults three or four times, eating hungrily in between until in about three weeks it is fully grown.

Record these moults as seen in your insect cage.

Look for orange tree leaves with the edges eaten; a sure sign of the presence of butterfly caterpillars.

Caterpillars are the *larval* or second stage in the life history of a butterfly. This is the growing stage during which much food is eaten.

When it is fully grown the caterpillar moves to a twig or leaf stalk for the next or *pupal* stage of its life. It then fixes itself to the twig by silk threads and changes into a pupa, which is something new and quite unlike the caterpillar stage. It remains quite still without eating and becomes brown in colour, very like the stem to which it is attached.

The caterpillar of a moth spins a cocoon or tube of silk either on its food plant or on the ground. If you find any cocoons put them in your insect cage and watch their development.

Great changes are going on inside the body of the pupa. After about eleven days the skin of the pupa splits and the new butterfly comes out. This is called the *imago* stage in the life of the butterfly.

Moths are similar to butterflies in the form of their bodies and in their life history.

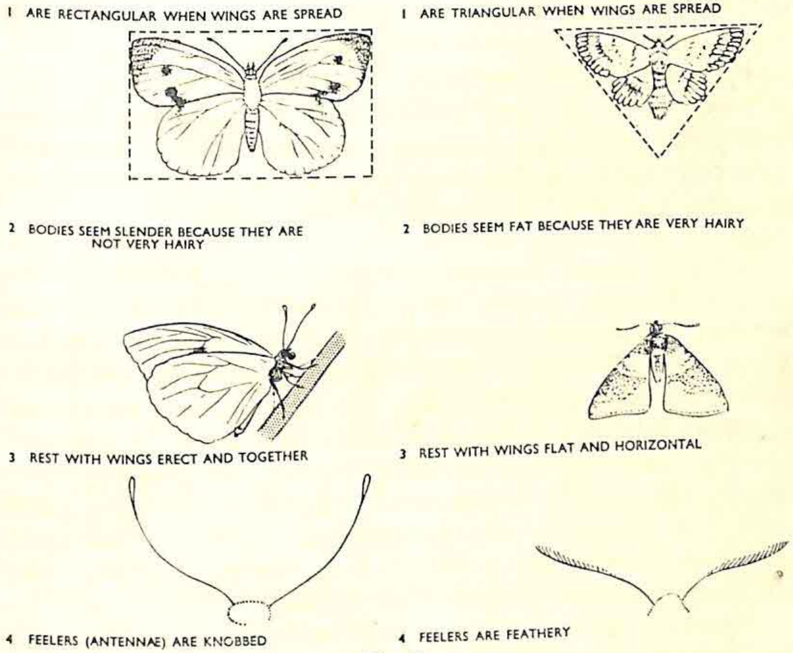
1 ARE RECTANGULAR WHEN WINGS ARE SPREAD
1 ARE TRIANGULAR WHEN WINGS ARE SPREAD
2 BODIES SEEM SLENDER BECAUSE THEY ARE NOT VERY HAIRY
2 BODIES SEEM FAT BECAUSE THEY ARE VERY HAIRY
3 REST WITH WINGS ERECT AND TOGETHER
3 REST WITH WINGS FLAT AND HORIZONTAL
4 FEELERS (ANTENNÆ) ARE KNOBBED
4 FEELERS ARE FEATHERY

Fig. 7.

Moths generally, however, fly at night while butterflies are seen mainly by day. Butterflies and moths have antennae on their heads; these are very thin jointed feelers. In butterflies the antenna is pin headed, while in the moths the antenna is pointed or it may be shaped like a comb. When butterflies are resting the wings come together over the body (a protection device in sunlight) but in moths the wings remain flat on the body (Fig. 7).

Look out for the Oleander Hawk Moth: dark green with pink and white markings on the wings, which are 4 ins. wide from tip to tip. It flies fast, its wings making a droning sound, but it can stop, with rapidly moving wings, in front of a flower. Then you may see its long tongue (proboscis) unroll and move down into the corolla tube of the flower in search of nectar.

Look for the greenish white eggs of the Hawk Moth on the underside of the leaves of Oleander shrubs. Put some soil in the insect cage; for the larva goes down into the ground to pupate (that is, for the second or resting stage of its life, when it becomes a pupa).

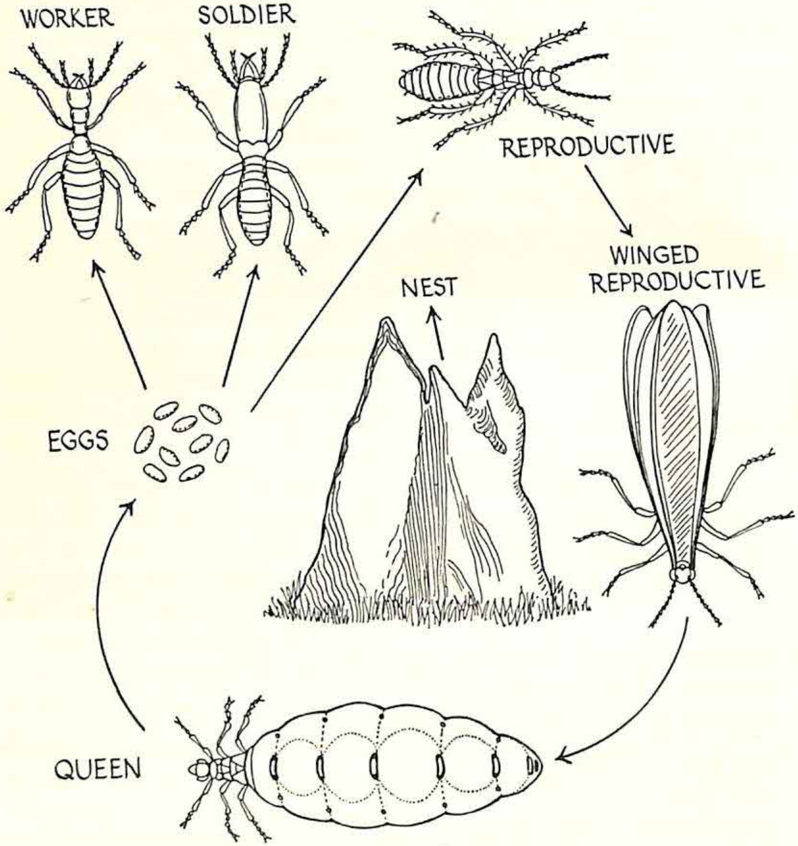

Fig. 8. The members of a White Ant (Termite) community. The nest which the Workers build may be ten or more feet high

SOCIAL INSECTS

There are many insects which live together in communities with customs and forms of government in some ways similar to those of our own cities. They have a division of labour; that is, there may be some groups in the community which go out to look for food, others which look after special gardens, others which keep the home of the community clean, care for the queen and feed the young larvae and others, the soldiers, whose duty it is to protect the community.

All these different members of an insect community depend on each other just as teachers, manual workers, farmers and soldiers depend on each other in our own communities. A community is a group of people with differing duties and common loyalties. The best known social insects are the honey bees, the ants and the wasps. 'Go to the ant, you lazy fellow; consider her ways and be wise,' said the writer of the Book of Proverbs. Men have long been amazed at the lives and work of the social insects and recent study has made them even more interesting. If you have the opportunity, study the lives of honey bees and of ants.

B. SOME VERTEBRATE ANIMALS

Fishes are animals which are better known when they are dead on a market stall than when they are alive in water. Very few people have any idea how many fishes there are in the sea or in the rivers. Make friends with fishermen and find out about the fishes of your local waters. Find out about the different fishes found in sea water, in fresh water and in the half salt, half fresh water of the tidal lagoons.

Examine a dead fish carefully with a hand lens: its mouth, eyes, gills, fins and scales. Then open it and discover the heart, the stomach and the swim bladder.

Remove the flesh either by boiling the fish or by burying it in sand where the ants may clean the bones and the sun may dry them. Compare the skeleton with that of any other vertebrate animal.

Put some live fish into an aquarium (or into a large glass jar full of water) with some green water plants in a cool place, watch the fish carefully to see how they move, how they breathe and how they feed.

Make careful drawings of the shape of certain fishes which can be seen in the market: the long thin barracuda, the short thick perch and the long snakelike eel: and find out how these shapes are suited to their ways of life.

Find out what is being done about fish-farming in your country and, if there is a fish farm not too far away, visit it and learn how the fish are bred and fed. It is said that more food can be obtained from a one-acre pond than could be harvested from a farm of the same size.

Toads and *Frogs* are amphibious: that is, they are animals which, when they are young, live in water and breathe by gills but when they are fully grown have lungs and can live in water or on land. Amphibians differ from fishes because adult amphibians have limbs with fingers and toes. In the Tropics toads which live mainly on land are more common than frogs, which are generally smaller and have smoother skins than toads.

Keep a pair of toads in an aquarium tank with several large stones as resting and hiding places and give them a daily supply of worms and insects.

Look for the egg spawn of toads and frogs. Toad spawn is in a double chain but frog spawn is in a mass of jelly balls with a black spot (the egg) in the centre of each. Note the time when they were found. Keep some of them in a large jar of water and water plants. Watch and record the development of the eggs into tadpoles and the time taken to change from the life in water to the life in air.

Look for eggs of the common garden *Lizard* in a hole in the sand. Put them in a cage in sunlight and watch the young hatch out. Study also, the Gecko, and the Chameleon. From your own observation, make a list of ways in which the lizard (a reptile) is different from the toad (an amphibian).

Watching birds is a hobby which has given great pleasure to men and women in every country in the world. Learn to spot the difference between the birds which pick insects off leaves (with a slender little beak like a pair of forceps), the birds which eat grain (with a short and powerful little beak) and the birds which eat flesh (with a strong curved beak). Learn to know birds, even at a great distance, by their flight: for example the noisy, rapid flight of pigeons, the fast and twisting flight of the swallows and swifts, the slow progress, up and down, of the hornbills, the tumbling flight of the rollers, the slow steady flight of a heron. Learn to know how the various birds move on land and try to recognise bird song.

Go out in pairs and take it in turn to be observer and recorder. Estimate the approximate size of any bird you wish to name (compare the size with that of some bird you know well). Note the type of beak and anything about its form or colour which will help to name the bird when you are able to look it up in a book.

MIGRATION

There are many birds which spend part of each year in one country and then move off to another country during the breeding season. We call these birds *migrants* and the journeys which they make, often in large numbers, *migration*. There are some storks which spend the dry season in Africa and then fly north to make their nests and rear their young in the European summer. There are other storks which spend the dry season in Africa south of the Equator and the wet season in Africa north of the Equator. As a rule, birds end a journey as far south of the Equator as they started north of it. There are some birds which spend part of the year in the Arctic and then fly all the way to the Antarctic.

So make notes of the dates on which birds such as the Bee-eaters, the Hoopoes and many other migrants arrive and depart. Many birdwatchers in other countries put numbered rings on the legs of young birds. The object is to find out how far and to what countries these migrating birds travel. So, if you see a dead bird, always look to see if it has a small aluminium ring on its leg: and, if it has, be sure to send the ring to the place named on it.

Fish also migrate. Some fish spend part of their lives in salt water and return to fresh water rivers to breed. Others move from deep water in the centre of a large river to the safety of shallow water before putting their eggs in the water. You may be able to see places on the bottom of a stream where stones have been brushed aside and paths made by the large numbers of fish swimming up it at the beginning of the rains, to reach safe places for breeding. Even butterflies migrate: sometimes they may be seen flying steadily, a few feet above the ground, in twos and threes, and in one direction for many hours. Sometimes they may be seen flying high like a cloud of locusts. Note these movements and record them.

THE MAMMALS OF TROPICAL COUNTRIES

The vertebrate animals classed as mammals are alike in that they have warm blood, a hairy skin and, in the females, milk glands with which the young are fed. They all differ greatly, however, in form and habits. It is on these differences that we divide them into the following and other groups:—

(*a*) the plant eating and hoofed mammals (the Ungulates) e.g. horses, sheep, goats, cattle, antelope, buffalo, camel, elephant, giraffe, hippopotamus and pig.
(*b*) the flesh eating mammals (the Carnivores) e.g. hyaena, leopard, lion and wild dog.
(*c*) the gnawing mammals (the Rodents) e.g. hare, mouse, rat, porcupine and squirrel.
(*d*) the higher mammals (the Primates) e.g. baboon, chimpanzee, gorilla and man.
(*e*) the fish-like mammals, e.g. whale and dolphin.
(*f*) the flying mammals, e.g. the bats.

The Manatee, a large mammal living in tropical rivers, is in a division by itself.

The animals named are only a few among the great family of mammals. You will see that they have been divided mainly according to the variety of their feeding habits which have variously affected the development of their bodies.

The flesh eaters have sharp teeth and claws for tearing food and they have strong legs with which they spring upon other animals. The plant eaters have teeth adapted for chewing large masses of green food: and they have long legs with which they can run away from the flesh eaters.

The skeletons of all mammals are similar although the bones differ in size and shape. For example, there are the same number of bones in the neck of a giraffe as there are in your own neck. All mammals, too, have four limbs and five fingers or toes on each; though in some animals these have become small and useless. Compare a skeleton of a mouse with that of some larger mammal such as a hare and note the similarity of all the parts. (Look back to Book 1, p. 102 for a note on the human skeleton).

The circulation of the blood is similar in all mammals and you will learn more about the human heart by asking a butcher to show you the heart of a bull than you will by studying pictures of your heart in a book.

Mammals have large brains with a developed and varied system of nerves sending messages to and from them. It is important to remember that mammals (and other animals) can therefore feel pain. In many countries cruelty to animals is a criminal offence. If animals have to be killed for food it should be done as quickly and painlessly as possible.

When looking at animals, note how much of their behaviour is inborn and instinctive and how little is due to the use of reason. Even among the higher animals, much behaviour is a matter of habit rather than intelligence A *habit* is an action, such as riding a bicycle, which had to be learned but which, when learned, is then done without thought. The nest building of birds and other instinctive actions have been passed on from adults to young because they were useful to the animals and have become racial habits.

SUMMARY

In this chapter you have learned about some of the vertebrate and invertebrate animals which you may find around your own homes and about their classification. You have also been led to look at the migration of birds and other animals and to consider the variety of the mammals to be found in the tropics.

THINGS TO DO

(1) Count the number of animals in soil. Mark out a square foot of grassland (in the rainy season) or a square foot of forest soil. Note the plants growing within this area. Then remove the top inch of soil and put it in a paper bag (or a folded newspaper) and mark it '1st inch'. Remove the second inch of soil and mark it '2nd inch'. Continue to remove an inch at a time until you have reached hard subsoil. Now open each parcel and collect from each all the small animals you can find, putting them into separate tins marked according to the level at which they were found. Record the total number of animals and the kinds of animals found at each level.

(2) Find a large earth worm. Lift it carefully and place it on the stretched surface of a drum. Listen carefully when the

worm begins to move. Also rub a finger lightly along the underside of a worm to feel the bristles.

(3) With a hand lens, examine the hind legs, the wing cases, the 'ears' and the egg laying tube of a grasshopper.

(4) See what weight a snail can pull along a level surface.

(5) Put the eggs of butterflies or moths into an insect cage with some leaves of the shrub on which they were found. Watch them for some days and record what you see.

(6) Scrape a few scales off the wing of a dead butterfly or moth and examine them with a hand lens or microscope.

(7) With a hand lens, look at the leg of a house-fly. Note the bristles, the claws and the sticky pad.

(8) Compare the form and size of a queen, a drone and a worker honey bee and look for the pollen bags on the worker bees' legs. Look at some honeycomb and measure the diameter of the cells carefully.

(9) Watch a pair of birds feeding their young in the nest and count the number of times food is brought to the nest during one day. (Be very careful not to be seen by the birds.)

(10) Look out for and record the dates of the migration of birds and other animals.

QUESTIONS

(1) It has been stated that a queen termite lays eggs at the rate of 60 a minute. Try to check this figure.

(2) What alarm signal is given by termites when they are disturbed?

(3) What are social insects? Calculate the number of locusts in a square quarter mile, if there is one on every square inch of the ground.

(4) Why do ticks climb up grass stems? How high will a tick climb if it is placed on a piece of string hung from the roof?

(5) In what ways are fish well adapted to life in water? Why does a dead fish float?

(6) Name ten kinds of animals which do not have backbones.

(7) In what ways do insects differ from other animals?

CHAPTER 5

Heat Energy

LIGHT AND HEAT

You have already seen that you can use a hand lens to bring rays of light together in a very hot point You also know that when you switch on an electric light the bulb soon becomes so warm that you cannot hold it. Have you ever asked how light and heat are related in these ways?

You know that energy is the power to do work (Book 1, p. 103). Light, heat and electricity are three forms of energy and each form can change or be changed into any other form. For example, the heat of the sun causes air containing water vapour to rise, the water comes down as rain and the force of falling water can be changed into electricity. So heat energy becomes electrical energy which, in turn, can change into heat, light and any other form of energy.

Energy can neither be made nor destroyed; it only changes its form. We receive energy from the Sun but the Sun itself does not make energy. It is only a great storehouse of energy.

With a hand lens, shine the sun's rays on the bulb of a thermometer. Note what happens. See whether you can use sunlight to boil water in a flask.

THE MOVEMENT OF HEAT BY CONDUCTION

Hold a length of steel in your hand and then hold a piece of wood (both of which are at room temperature): the metal feels colder because it carries heat rapidly away from your hand. Substances through which heat passes quickly and easily are called *conductors* of heat. Fill a tin with very hot water. Can you hold it with your bare hands? Put on woollen or leather gloves and hold the tin. You can do so without difficulty because such materials are bad conductors of heat.

Metals generally are good conductors With candle wax or vaseline fix some small nails or tacks one inch apart on a metal rod (at least $\frac{3}{8}$ in. diameter and 12 ins. long). Set the rod up as

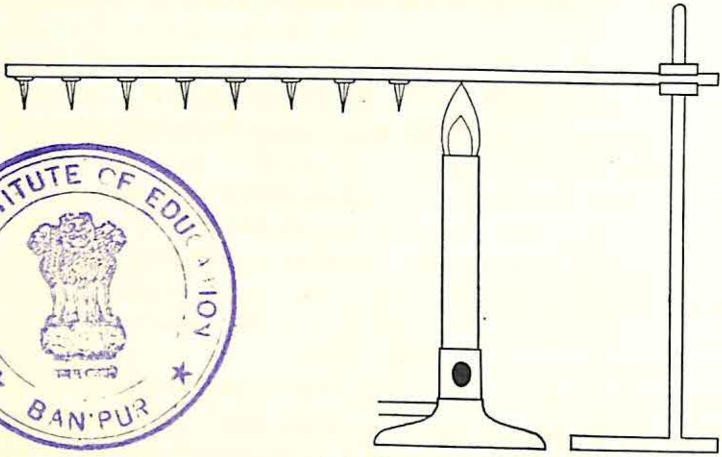

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Fig. 1.

in Fig. 1. and heat one end. How do you see that the heat travels along the rod?

Water is a poor conductor of heat. Take two pieces of glass tube (about twelve inches long). Join them at the bottom with a short length of rubber tube. Put a clip on the tube. Clamp the glass tubes vertically. Fill one with hot water and the other with cold water. Close each tube with a rubber stopper fitted with a thermometer and lay the tubes flat on a table. Then remove the clip and take the temperature in each glass tube at five minute intervals.

The poor conductivity of water can also be shown in this experiment. Fill a test tube with cold water and put a small piece of ice in the bottom of the tube. Then hold the tube as in Fig. 2 and heat it near the top. Does the ice melt when the water boils?

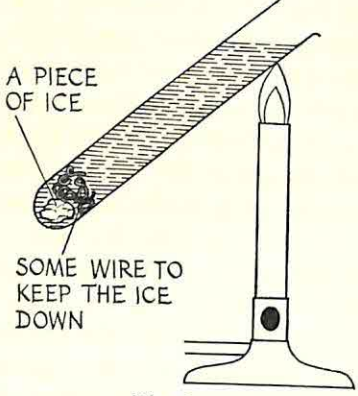

Fig. 2.

HEAT MOVEMENT BY CONVECTION

Although water is a poor conductor, heat travels through it fairly quickly by convection;

that is, by movement caused by the differing densities of hot and cold water.

Fill a large (1 litre) beaker with cold water containing some fine sawdust and let it become quite still. Then, heat the beaker gently, using a small flame. What happens to the sawdust in the beaker?

Heated water expands: so it becomes less dense and rises. Then cold water flows down to take its place. You have already seen that there are similar convection currents when air is warmed (Book 1, p. 36).

HEAT MOVEMENT BY RADIATION

Heat energy given out by the Sun travels 92,000,000 miles through almost empty space to reach this Earth. It travels by means of rays which are very like light rays. Heat rays travel in straight lines. They can be reflected from a polished surface just as light is reflected by a mirror. They can be focused by a burning glass. They travel at the same speed as light and they are stopped by walls and other solid objects. Dark coloured surfaces, which take in most of the light falling on them and which reflect very little light, also absorb radiant heat rays and become warmed by them. Pale coloured surfaces which reflect almost all the light rays also reflect heat rays. White roofs, white walls and white clothing reflect heat and keep houses and people cool in the tropics.

Take two pieces of white cotton material about one foot square. Make one of them very black with soot. Place the white material on a table in the sun folded so that there are four thicknesses of material above and below a thermometer. Do the same with the piece of black material. Test and record the temperatures of the two thermometers at five minute intervals. Which material absorbed the greater amount of heat? What was the difference in the temperatures recorded after fifteen minutes? Which material is more protective against heat rays?

Radiation from different surfaces: take three empty food cans of equal size (about 3 in. diameter and about 4½ ins. high). Paint one of them dull black inside and out, paint another white and leave the third unpainted. Fill them with very hot water. Record the temperatures. Put a cardboard or metal cover on each can and stand them in a cool place. Test and record the temperature in each can at intervals of five minutes. In which can did the water cool most rapidly? In which can did the water remain warm longest? Record these results.

Now fill the three cans with cold water. Record the temperature. Cover the cans and stand them in the sun, at an equal distance from a hot wall. Test and record the temperature of the water in each can at five minute intervals. In which can did the temperature rise fastest? In which can did it remain cool longest? Record these results.

KEEPING HEAT IN AND KEEPING IT OUT

It is often necessary to keep some things hot and other things cold. We need to keep heat in containers of hot food and drinks and to keep heat out of containers of ice cream and cold drinks. We can do this with insulating materials and by means of vacuum containers.

Any materials which hold air in small pockets, for example woollen blankets, cork chips or glass fibre are good insulators because they hold air, a bad conductor, and do not allow it to carry heat away by convection. We wrap these insulators around hot water tanks to keep them hot and around water pipes (e.g. on ships) to prevent them becoming too cold. We call this 'lagging' the pipes. We also use these materials in the roofs of houses both to keep heat out in hot weather and to keep heat in during cold weather.

Food can be kept at cooking temperature for some hours, without burning any fuel, by placing the cooking pot and its boiling hot food in a box and packing straw around them. This is called a Norwegian oven.

It is well known that a grass roof, holding air between the straws, keeps out the heat of the sun on hot days and keeps heat in the house on cold days. Find two buildings of about the same size, one with a thatch roof and the other roofed with corrugated iron. Place a thermometer under each roof (above the ceiling) and compare the temperatures on a hot day. Note also the thick walls and roofs which keep houses cool on the borders of the desert in Africa and Arabia.

A vacuum is an empty space. It is impossible to have a completely empty space but we call any space a vacuum if it contains very little air or other gas. There is a vacuum, for example, at the top of a mercury barometer.

We use a vacuum flask (often called a 'thermos' flask) to keep liquids and other substances hot or cold. As there are no (or very few) material particles in a vacuum, heat cannot pass through it by conduction or convection (Fig. 3).

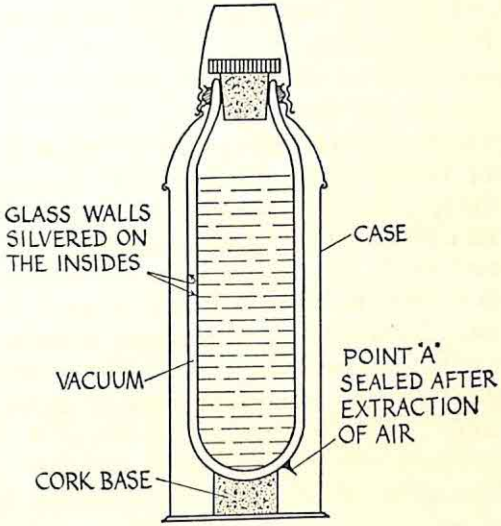
GLASS WALLS SILVERED ON THE INSIDES
CASE
POINT 'A' SEALED AFTER EXTRACTION OF AIR
VACUUM
CORK BASE

Fig. 3. A vacuum flask

The flask has a glass container which has double walls and the space between them is the vacuum. Heat could pass through the vacuum by radiation, just as light can pass through the vacuum at the top of a barometer tube. So the walls of the glass container are silvered to prevent any radiation. The glass container is generally placed in an outer metal case to protect it. It is usually possible, with care, to unscrew this to examine the glass container. You should understand that a vacuum flask is used to keep substances at a desired temperature and that, because the vacuum is not completely empty, it can only do this for a time There is some conduction of heat through the walls of the flask and therefore some change of temperature inside it.

REFRIGERATION

The first successful ice-making machine was invented in 1834 and until about 1930 the only ice in tropical countries was made in a few 'Cold Stores' from which blocks of ice were bought and put into the 'ice boxes' of those who could afford them. However, now, with the coming of electricity more and more homes have the more efficient and cleaner refrigerators. How do they work?

Fill one drinking glass with crushed ice and another with ice cold water. Put them both on a table where they can take in equal amounts of heat from the air. See how many minutes longer are required for the ice to melt and reach room temperature than is required for the water in the other glass to reach the same temperature. While the ice was melting did the temperature of the ice rise?

The fact that ice can take in a lot of heat without getting warmer is used to draw heat away from food and drink, so making them cooler. Refrigeration is cooling a substance by taking heat away from it. Conduction, convection and radiation —these ways in which heat energy moves from place to place — all play their part in this important work of making things in the tropics cooler.

AIR CONDITIONING

Nowadays, many offices and homes in the tropics are using machines which control the amount of water vapour in the air and also clean and cool the air. This is called air-conditioning. As you have seen on p. 12, warm air holds more moisture than cold air. You also know that our bodies perspire partly to keep us cool. If there is a lot of water vapour in the air perspiration evaporates slowly and less heat is carried away from your body. You are too warm. So in tropical countries where the humidity of the air is often as high as 80% the first job of the machine is to reduce air moisture; it does this by passing the air over cold pipes: the moisture condenses on them and is drained away. At the same time the air is cooled by the pipes.

THE EXPANSION OF SOLIDS, LIQUIDS AND GASES

You have already learned in Book 1 that air expands when heated and you know that mercury expands in a thermometer.

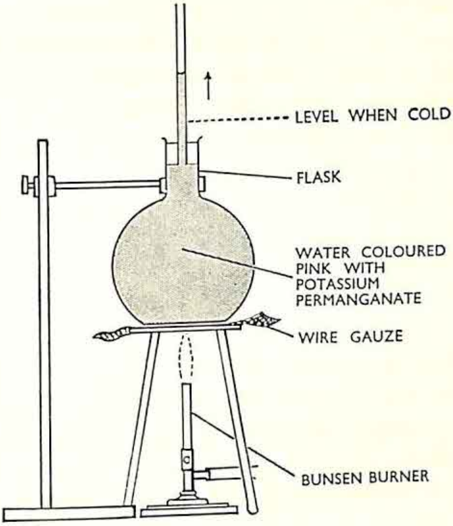

Fig. 4. Heating a liquid

Set up the experiment shown in Fig. 4 to see whether water also expands.

Take a bar of iron (or any other metal) at least 12 ins. long, and set it up as in Fig. 5. The free end rests on a knitting needle which has been bent at right angles at one end to form a pointer. The bar should be weighted so that it presses on the needle. Then heat the bar and note the expansion.

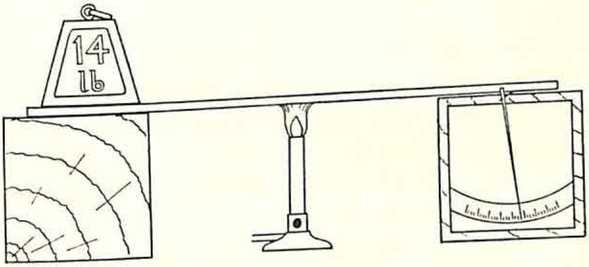

Fig. 5. Heating a solid

African blacksmiths heat thin iron rods and wind them round the wooden handles of farm tools, knowing that, as the iron cools it will contract and hold the tools firmly in the handles.

Iron tyres are fitted to the wooden wheels of farm carts in the same way: they are made rather smaller than the wheel to which they are to be fitted. Then the iron tyre is heated and hammered into position. As it cools, it contracts and is firmly fixed to the wooden wheel. Steel tyres are fitted to the wheels of railway engines in the same way. Shipbuilders and other iron workers heat the rivets with which steel plates are joined. The hot rivets are hammered tight and, as they cool, the plates are pulled together. Note the large number of rivets used in the building of a steel bridge.

These are examples of the ways in which the expansion and contraction of iron has been used to bind things firmly together. Often however special care has to be taken to allow metals to expand and to correct any errors caused by the expansion. Look for example at a railway line. Note the gap left for expansion between each length of rail. Also, if there are any large steel road or rail bridges in the district, try to see how they expand during the midday heat.

THE UNEQUAL EXPANSION OF METALS

Take a piece of baling iron, about 6 ins. long (or cut a piece of roofing iron about $\frac{3}{4}$ ins. wide and 6 ins. long). Then cut a

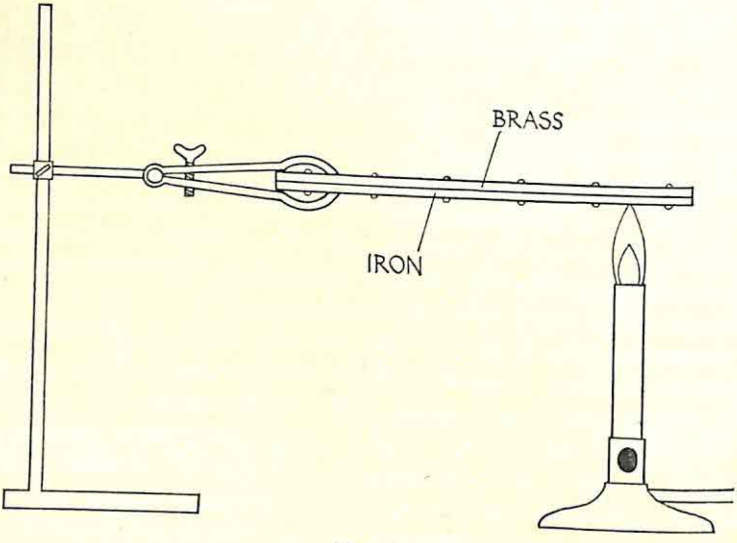

Fig. 6.

piece of brass or aluminium sheet of the same size. Place them together and make three holes with a 2 in. nail. Bolt them together with small screws or rivet them together with rivets cut from the 2 in. nail. (Joined in this way they form a bimetallic strip (Fig. 6).) Hold one end in a clamp and heat the strip. Note what happens. Allow the strip to cool; turn it over and heat the other side. Again note what happens. Did the strip bend the same way each time you heated it?

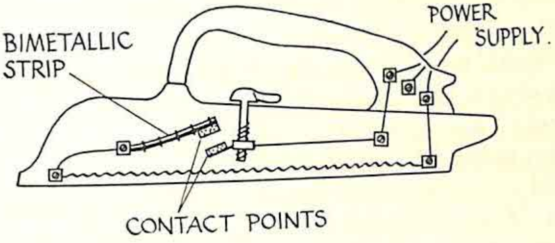

Fig. 7. Thermostat in electric iron

The greater expansion of one of the metals makes one side of the strip longer than the other. Hence, as the two pieces of metal are joined together, the strip bends towards the shorter piece of metal. Note that as the strip cools it becomes straight again. This bending of a bimetallic strip when heated is used in some thermostats.

A *thermostat* is a switch set to control the supply of fuel as required. Probably the best known example is in the heat controlled electric smoothing iron. The switch is turned to the desired temperature mark and at that point the electric current is switched off by the bending of a bimetallic strip. When the smoothing iron cools, the strip contracts and the electric current is switched on again (Fig. 7).

Another example is the thermostat in an electric refrigerator which switches on the compressor motor when the temperature in the refrigerator rises above a certain temperature. In some thermostats the expansion of mercury or of a gas in a tube is used to start and stop the flow of electric current. In others the expansion and contraction of a long bar of metal is used to open and close a valve.

SUMMARY

In this chapter you have learned that heat and light are two forms of energy and that heat energy moves from one place to another by conduction, convection and radiation. You have seen that heat is taken out of things: for example in refrigeration and air conditioning, and you have learned how heat may be controlled by thermostats.

THINGS TO DO

(1) Find how domestic animals keep themselves cool on a hot day.

(2) Add 500 c.c. of water to 500 grams of quicklime and when bubbling ceases record the increase in temperature.

(3) Record the temperature of a piece of iron. Rub it vigorously on a stone and again record the temperature.

(4) Find out how the engine of a motor car is cooled.

(5) Put 500 c.c. of water at 0°C. in a vacuum flask. Close it and leave it in an airy, shaded place for twenty-four hours. Then test the temperature of the water.

(6) Repeat that experiment but start with 500 c.c. of water at 100°C.

(7) Ask a watch repairer to show you the balance wheel in a good watch and the way in which it is able to expand in hot weather without causing the watch to gain or lose time.

(8) Ask a mechanic to show you the thermostat in a refrigerator or in an electric iron.

QUESTIONS

(1) What is the internal temperature of a healthy human body and of a domestic fowl? (Put the thermometer under its wing for a minute)

(2) (*a*) What is the name of the method by which heat travels along a solid?

(*b*) What is the main method of heat transference in liquids and gases?

(3) Why does an iron roof make cracking noises in the evening after a very hot day?

(4) Why does a hot liquid generally become cold if kept for more than 24 hours in a vacuum flask?

CHAPTER 6

Light Energy

WHAT IS LIGHT?

You have already learned that light is one of the forms of energy. Most of the light we use on the Earth comes from the Sun: a very much smaller amount comes from the stars. Other sources of light which we use at night (for example, candles and kerosene lamps) use energy which came originally from the sun. Until recently electric lights obtained their power solely from the energy of the sun stored in coal and other fuels and in water. Now we have begun to make electric light from the energy stored in atoms.

HOW DOES LIGHT TRAVEL?

Light travels from the sun or from any other source of light at a very great speed (186,000 miles per second). We say that light radiates from its source: it travels out in all directions, in rays or straight lines. Its speed is greater than anything we know; it is so great that it *seems* to take no time at all to travel from one place to another.

WHAT IS RADIATION?

We can see radiation or wave movement in water. Throw a stone into the middle of a still pond. The weight of the stone causes waves to travel out in circles, growing larger and larger. At first, the waves are strong and deep but as they radiate further from the centre they become weaker and flatten out until they can no longer be seen.

If you have no suitable pond take a large basin full of water. When the water is still, let one drop of water fall from a height of more than 12 inches into the centre of the bowl. Does the wave produced by the falling drop travel outwards? What happens to the wave when it reaches the sides of the bowl?

Note what the wave does to a leaf or a small piece of wood floating on the water. Is the leaf carried forward by the wave or does it stay in one place and merely bob up and down? This may show you that, while energy is carried forward by waves, the material particles of which the waves are composed do not themselves move forward.

LIGHT TRAVELS IN A STRAIGHT LINE

Put a small piece of paper on a shaded wall. Stand some yards away with a hand mirror and direct a beam of sunlight so that

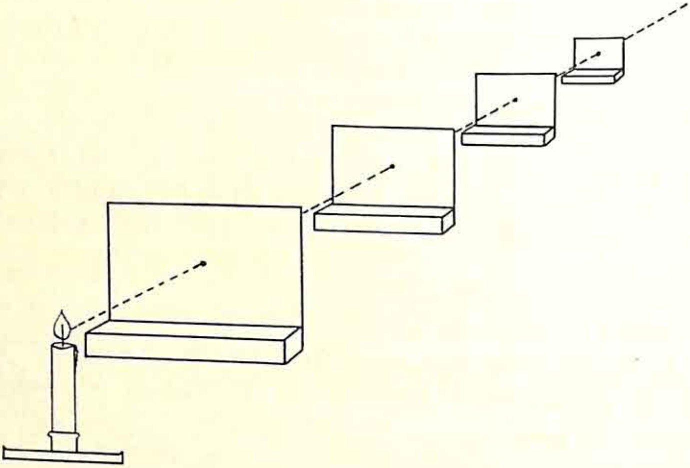

Fig. 1. Light travelling in a straight line

it falls on the paper. You will be able to move the beam to any place on the wall. The beam is made up of parallel rays of light.

Cut four pieces of tin about four inches square and nail along one side of each of them a piece of wood about one inch square

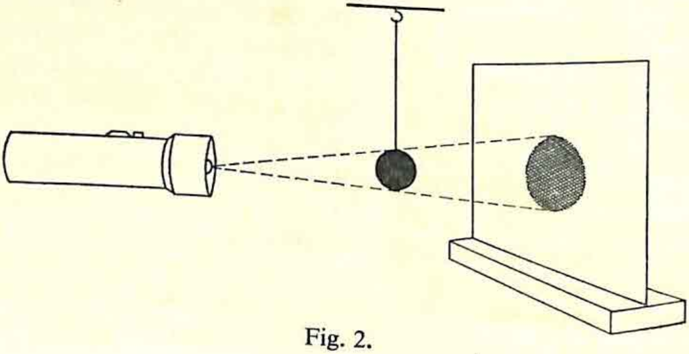

Fig. 2.

and four inches long so that the pieces of tin may stand upright. Exactly in the centre of each tin make a hole with a two-inch nail. Now set up the pieces of tin, spacing them about 12 ins. apart, so that you can look straight through all four holes (Fig. 1). Place a candle so that it can be seen shining through the four holes. Move one piece of tin so that its hole is not quite in line with the others. Can you still look through the four holes and see the flame? What do you learn from this experiment?

In a darkened room set up an electric torch so that it shines on a white wall. Hang a ball between the torch and the wall (Fig. 2). The shadow seen on the wall is due to the fact that rays of light travel in straight lines.

THE REFLECTION OF LIGHT

You have seen that a wave travelling from the centre of a basin of water is reflected (or turned) back from the sides of the basin. In the same way, light rays are sent back from any surface on which they fall. Shine a torch on to a wall, some of the light waves are reflected back to your eyes. You see a light patch on the wall.

Shine a torch so that its light meets a mirror or a polished surface: note that most of it is reflected in one direction (Fig. 3). When a light falls on rougher surfaces such as a tray of sand or a piece of cloth or paper it is reflected in many directions. The light is scattered (Fig. 4).

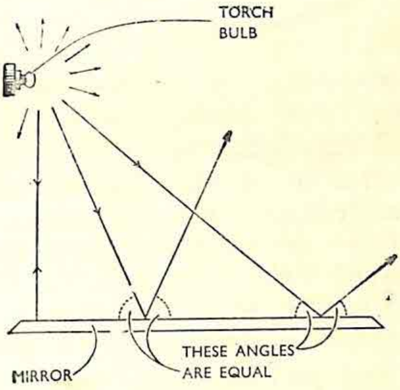

Fig. 3.

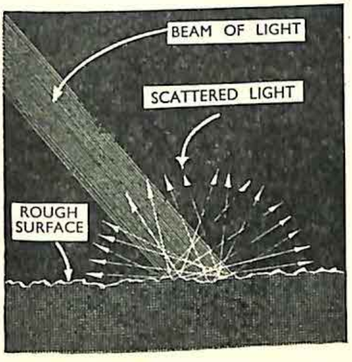

Fig. 4.

On many moonlight nights you can see the shadow of the Earth on part of the Moon. When the

Moon is completely in the shadow of the Earth it cannot be seen. The Moon is not a real source of light. It is only a reflector of the light of the Sun. Sometimes, when the Moon passes between the Sun and the Earth, a shadow of the Moon is cast on the Earth. People in that shadow cannot see the Sun and we say that there is a total eclipse of the Sun (Fig. 5).

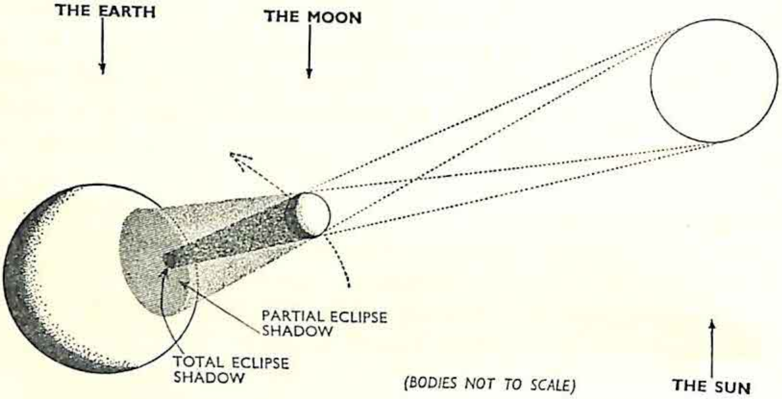

Fig. 5. Eclipse of the Sun

A tennis ball thrown straight down at the ground comes back along the same line; but if it is thrown to hit the ground at an angle it goes off at the same angle in the opposite direction. Light does the same when it hits a plane mirror: (that is one which is flat, for example, a looking glass). Look again at Fig. 3.

Stand a plane mirror on a sheet of paper. Place a pin upright an inch or two in front of the mirror. Set up two sighting stools (Fig. 6) so that you can see a mirror image of the pin through each of them. Then with a pencil draw two lines on the paper to show the paths of the rays of light from the mirror to your eye. Draw a

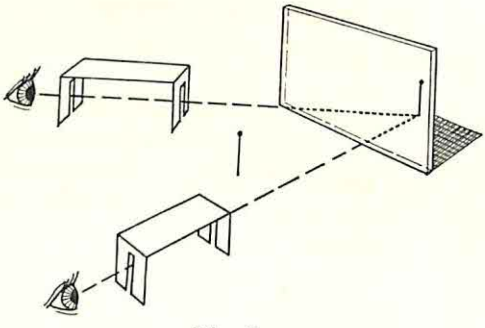

Fig. 6.

line also on the paper along the face of the mirror to mark its position. Then remove the mirror and continue the light ray lines, behind the mirror line, until they meet. Where they meet is the apparent position of the mirror image of the pin. Draw a line from that point to the pin. Compare the distance along that line from the pin to the mirror and from the mirror image to the mirror.

Stand in front of a plane mirror. You see a reflection or image of yourself because light from you is hitting the mirror and being reflected back to your eyes. At what distance behind does your image appear to be? Are you and your mirror image the same size? On which side of the mirror image is your left hand?

The chromium-plated hub covers on motor car wheels, the backs of polished spoons and many other common objects are also mirrors. Such mirrors in which the reflecting surface bulges outwards are called convex mirrors. Concave mirrors are shaped like the hollow side of a spoon.

ILLUMINATION

We see objects such as the Sun, a lamp or a glow-worm because they make light and send it out in all directions. Most objects do not make light. We can only see them if light falls on them and if some of it is reflected to our eyes.

When light falls on an object, for example on the page of this book, we say that the object is illuminated. Illumination is a measure of the amount of light falling on one square foot of an object. Two similar lamps placed side by side will give twice the illumination given by one, three lamps will give three times as much illumination as one, and so on. The illumination on a surface is proportional to the strength of the source of the light.

The distance of the surface from the source is also important. If you are reading one yard from a light and then move to a chair two yards from the light, only one quarter as much light will fall on the book (Fig. 7). If you move three yards from the light only one ninth of the original light will fall on the book. The further you move from the light the weaker will be the illumination on the book. How you hold your book is also important. When the page is directly facing the light, more

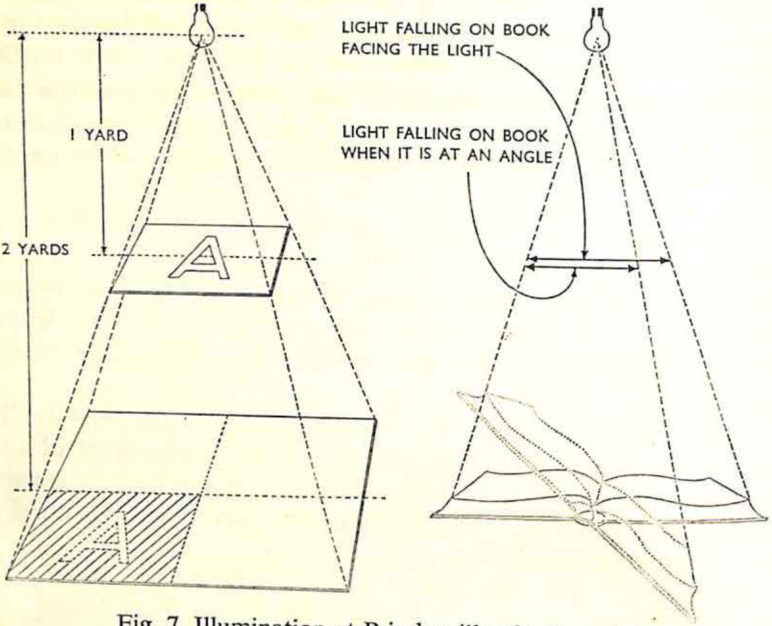
1 YARD
2 YARDS
A
A
LIGHT FALLING ON BOOK FACING THE LIGHT
LIGHT FALLING ON BOOK WHEN IT IS AT AN ANGLE

Fig. 7. Illumination at B is $\frac{1}{4}\times$ illumination at A

light falls on it than when it is held at an angle and so the illumination is better.

THE BENDING OF A RAY OF LIGHT

When a ray of light passes from one substance to another there is sometimes a change of direction. We say that the ray is bent. This is because the ray goes forward, making an angle with its former line of direction.

Take a large empty bowl and put a penny on the bottom.

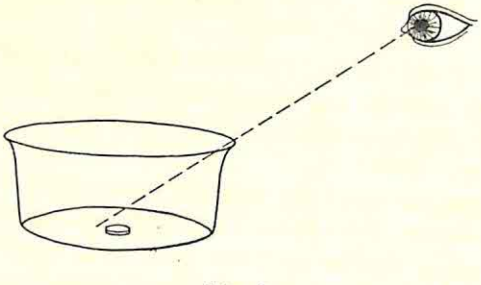

Fig. 8.

Move back until the penny is just hidden by the rim of the bowl (Fig. 8). Stand quite still and do not move your head, while water is poured slowly into the bowl. What happens to the penny? The next experiment will help you to understand why this happens.

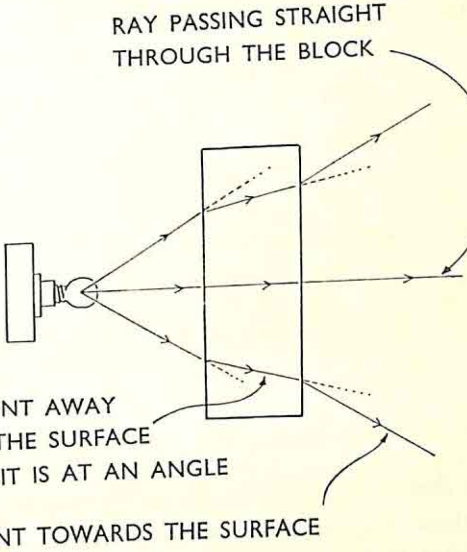
RAY PASSING STRAIGHT THROUGH THE BLOCK
RAY BENT AWAY FROM THE SURFACE WHEN IT IS AT AN ANGLE
RAY BENT TOWARDS THE SURFACE

Fig. 9.

Place a 12-inch ruler at an angle to the surface of the water with one end touching the bottom of the bowl. Look at the ruler in the water. Does it appear to be straight? Take it out of the water. Is it bent?

Now hold the foot rule upright in the bowl of water. Note that the inches above the water seem to be longer than those in the water. They appear to grow longer or shorter as you move the rule up and down in the water.

Light travels more quickly through air than it travels through denser materials such as glass and water. So when a ray of light passes from water to air it bends towards the surface of the water.

In Fig. 9 light is passing from air into a glass block and out into the air again. Notice how the rays of light except the one which hits the surface of the block at right angles are bent as they enter and again as they leave the block.

IS WHITE LIGHT ALWAYS WHITE?

You can see the colours of the rainbow when sunlight passes through a glass of water or through a triangular block of glass called a prism (Fig. 10). Catch the coloured beam on a white screen. The band of colours is called a spectrum. The colours violet, blue, green, yellow, orange and red which you can see when white light is split up run smoothly into each other.

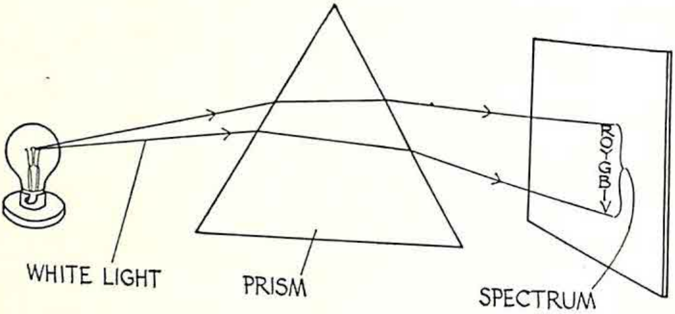

Fig. 10.

See whether you can unite the coloured rays of light with a second prism and make white light again.

A rainbow is formed when sunlight passes through raindrops and is broken up into lights of different colours.

Each raindrop acts as a small prism. You can make a rainbow if you stand, before 9 a.m. or after 4 p.m., with your back to the sun and squirt water into the air with a hose or a pump.

WHY THINGS ARE COLOURED

An Allamanda flower looks yellow because it reflects only yellow light to your eyes. If you hold the flower near your skin you will see that it reflects yellow light on to it. You have observed that daylight is a mixture of all the colours of the rainbow. When it falls on the petals of the Allamanda, yellow is reflected and the other colours are taken in or absorbed. In the same way grass looks green because it reflects green light.

LIGHT RAYS AND THE CONVEX LENS

Look at your hand lens. Notice that it is thicker at the centre than it is around its edge. For that reason it is called a *convex* lens. (A lens which is thinner at the centre is called a *concave* lens). A convex lens can be used to make things appear larger: it is called a magnifying glass.

When you use your hand lens to bring rays of light together (Fig. 11) the hot point at which they meet is called the *focus* of that lens (from the Greek word: *focus*, a fireplace.) The distance between the centre of the lens and the point where the rays come together is called the *focal length* of that lens.

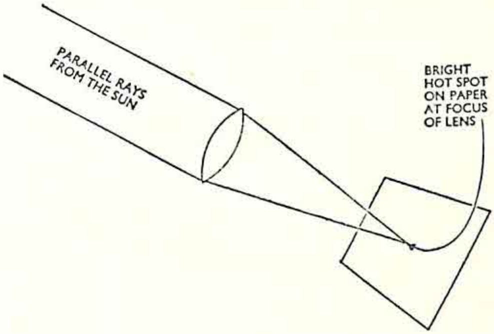
PARALLEL RAYS FROM THE SUN
BRIGHT HOT SPOT ON PAPER AT FOCUS OF LENS

Fig. 11.

The more rounded the surface of the lens, i.e. the thicker it is in relation to its diameter, the shorter is its focal length and the greater is its power to enlarge an image. Fill a clear glass bottle with water and lay it on its side across two bricks in sunlight. Hold a piece of paper underneath the bottle to find the point where the rays of sunlight are focused. Measure the focal length: from centre of the bottle to the bright spot on the paper.

Light and your eyes. The eye is a ball filled with a clear jelly through which light can travel. No light can enter the eye except at the front where there is a piece of hard transparent material shaped like a small hand lens. Rays of light passing through the lens are focused in the back of the eye on a layer called the *retina* (Fig. 12). There a picture is formed and carried to the brain by the optic (eye) nerve.

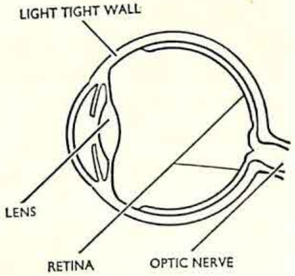

Fig. 12. The eye

The eye works like a small camera.

So, to understand how an eye works you should make a pinhole camera. You will need a cardboard or tin box about 3 ins. or 4 ins. wide and high and about eight to ten inches long. Then you can make the camera as follows (Fig. 13).

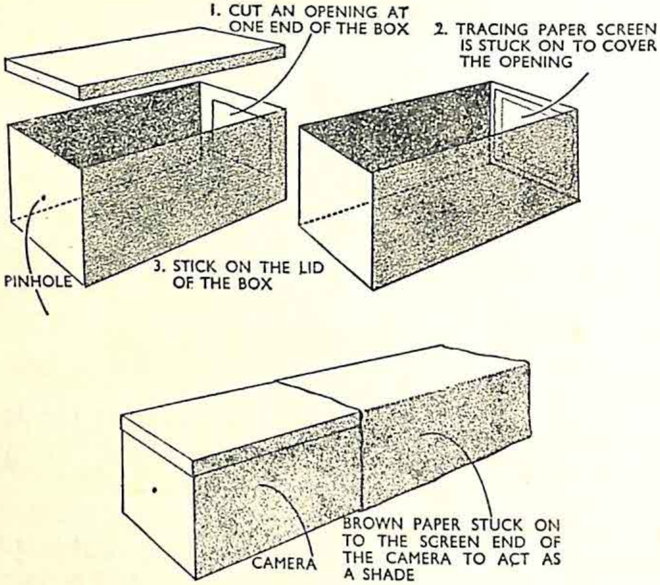
1. CUT AN OPENING AT ONE END OF THE BOX
2. TRACING PAPER SCREEN IS STUCK ON TO COVER THE OPENING
PINHOLE
3. STICK ON THE LID OF THE BOX
BROWN PAPER STUCK ON TO THE SCREEN END OF THE CAMERA TO ACT AS A SHADE
CAMERA

Fig. 13.

If you point your pinhole camera at a window or at a light, a picture can be seen on the tracing paper screen. Which way up and which way round is it? Can you see it easily? (You will see better if you cover your head with a dark cloth). Now make the pinhole a little larger and notice what happens to the picture. Keep on making the hole larger until it is about half an inch in diameter. If you have a magnifying lens you can put it in front of the hole to see what sort of picture it will give on the screen. You have now changed your pinhole camera to a box camera which uses a convex lens to focus a picture (=image) on the screen.

Light from all parts of an object in front of the pinhole camera travels in straight lines through the hole and hits the screen at the back of the camera. You can see from the drawing

(Fig. 14) how the picture of the boy is formed and why it is upside down and left to right.

In most cameras the lens can be moved forward or backward in order to get a clear picture of near and distant objects. In the eye, without our knowing about it, the lens changes thickness in order to focus a picture of the thing we are looking at on the retina.

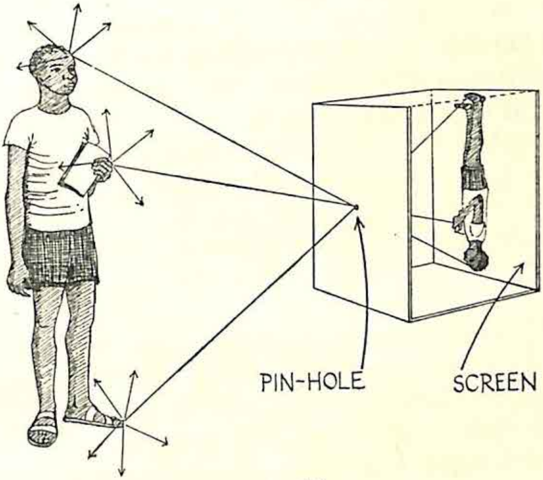

Fig. 14.

In our eye, as in the camera, the picture of the outer world is upside down on the retina. Our brain, however, reverses the picture and so we see things the right way up.

HOW SOME ANIMALS SEE

Many animals have eyes like ours. Some, such as the hawks, have eyes which are even quicker than ours at seeing small things at a distance. Others, such as the owls, are better able to see in the dark than we are. Birds and other animals with eyes at the sides of their heads can see behind them without turning their heads. In many animals each eye moves by itself. Some insects have compound eyes: that is, eyes in which there are many very small lenses instead of one. Each lens helps to build up the picture which the insect sees. Earth-worms have no eyes. They sense light by nerve endings in the skin. They move away from light, coming above ground mainly at night.

LIVING THINGS AND LIGHT

Sunlight is essential for the health of our bodies. So working and playing in sunshine is good for us. There are some diseases which are due to a lack of sunshine, and, in countries where there is sometimes little sunlight, artificial sun lamps are used in hospitals.

Sunshine which is too strong can be harmful to living things. Perhaps you can name some plants in which the leaves are brown. When such young leaves first open they are soft and might be burned by the strong sun of the Tropics. The brown colour protects the young leaf until its outer covering has hardened. It then becomes green.

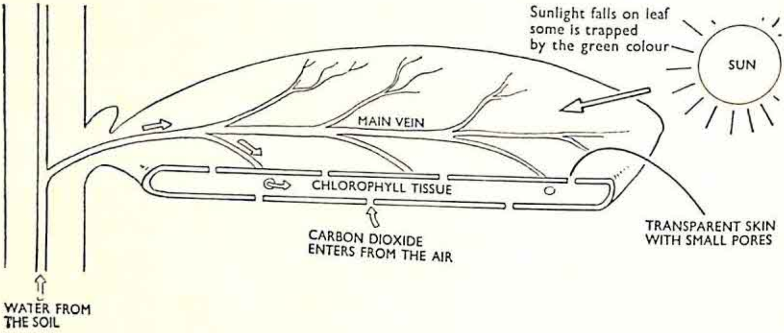
Sunlight falls on leaf some is trapped by the green colour
SUN
MAIN VEIN
CHLOROPHYLL TISSUE
CARBON DIOXIDE ENTERS FROM THE AIR
TRANSPARENT SKIN WITH SMALL PORES
WATER FROM THE SOIL

Fig. 15. Green leaves are factories in which food is made

GREEN LEAVES NEED LIGHT FOR FOOD MAKING

You learned in Book 1, Chapter 5, that carbon dioxide and water are joined together in a plant to make sugar and starch. You also learned that this can only happen if the plant has the green substance, chlorophyll, in its leaves and if there is sunlight (Fig. 15). This food-making in green plants is called *photosynthesis*: which means 'joining together by light'.

PLANTS IN SUNLIGHT AND DEEP SHADE

Shoots grown in sunlight are sturdy and green. In a dark room they become very long, weak and yellow. Light is needed for healthy growth. Green shoots, placed in a room near a window, sense the light and grow towards it.

The leaves of a tree are generally spread out so that they do not shade each other and each leaf gets as much light as possible. Note local examples of this. If there is any high forest in your neighbourhood compare the light under the forest canopy with that under trees in more open places. Count the number of plants growing in a square yard of soil between the trees in high forest and the number growing in the same area in a less shaded place.

COLOUR AND ANIMAL LIFE

Look at a fish. Seen from above its back is the colour of the bottom of the river, lake or sea in which it lives. So it is not easy for its enemies, fishermen or fish-eating birds, to see it. Seen from below, the fish is white like the sky: so its enemies in the water, other fishes and fish-eating animals such as the otter, do not easily see it. Sometimes when a fish moves suddenly you see a flash as it turns, showing the under part of its body, but it is only for a moment and then the fish is again hard to see.

The lion has the sandy colour of the dry grass or bare earth of the places where it lives. The small antelopes of the forests are darker than those of the open grasslands. The tall, grey heron standing at the edge of a river or in a marsh is hardly seen. The colour changes of the chameleon protect it from the keen eyes of passing hawks.

We call colouring which is like an animal's background, protective. Protective colouring is useful to animals which eat other animals and to those which may be eaten. For example, the grey cat and dull coloured mice.

SUMMARY

In this chapter you have learned that light waves travel very quickly and that although energy can be sent from one place to another by means of waves, the particles of which the waves are made do not themselves move forward. You noted that light travels in straight lines, that it is reflected and that a ray of light may be bent. You have seen that white light is composed of many coloured lights. You have done some experiments with light rays passing through a convex lens. After seeing how light enters the human eye you considered the eyes of some animals and the necessity of light for life.

THINGS TO DO

(1) Measure the focal length of your hand lens.

(2) Set up an electric torch, a convex lens and a piece of film strip so that a picture is projected on to a white screen. (The strip should be set at a point outside the focus of the lens, on one side of the lens, and the light should be placed on the other side of the lens at the focus.)

(3) Set up a plane mirror so that you may see round a corner.

(4) Make a periscope with two plane mirrors.

(5) Take a two inch nail and a six inch length of wire (about $\frac{1}{16}$ inch thick). Bend one end of the wire around the nail to make a little circle. Dip that end of the wire into water to pick up a drop. The drop of water in the wire circle can be used as a little hand lens.

(6) After sunset, look at the western sky. Then hold your ankle with one hand and look again at the same place. Note any change in the brightness of the light. (Bending the body causes the light to fall on a different part of the retina.)

QUESTIONS

(1) Which way up and which way round is the image formed in the camera and in the eye?

(2) How is a ray of light reflected from a plane mirror?

(3) What is the focus of a lens? What do we mean by focal length?

(4) Why should you turn a plant round daily if it is growing indoors by a window?

(5) What is the name of the part of the eye on which the picture we see is formed?

(6) What colours can you see in a rainbow or in the spectrum?

(7) Why is the red reflector on the back of a bicycle not always visible at night?

CHAPTER 7

Electrical Energy

Not very long ago, when the sun went down, men either burned oil in their lamps or went to sleep. If they had to travel any distance they either walked or rode on horseback. Now electricity has changed all that. We use it for lighting streets and homes, for sending messages by telegram and telephone and for broadcasting the sounds of radio and the pictures of television. Electricity is used for cooking, for heating, for cooling air and keeping food fresh. It is used to power sewing machines, washing machines and fans. Motor cars, trains and aeroplanes all use electricity in many ways and almost daily its power is being put to new uses. You must therefore know something about this form of power and about the circuits by which we lead it to the places where we wish to use it.

Note well, however, and never forget that while it is safe to experiment with the electricity in a few dry cells, such as you buy for a hand torch, it can be dangerous to touch a wire carrying an electric current. **It is very dangerous to use house current carelessly and it should not be used for experiments.** Handling house current can cause DEATH. Always switch off the current at once if any electric lamp or other appliance is not working properly: always switch off the power before lifting an electric kettle; and, if you use electric tools such as a hand drilling machine, stand on a rubber mat or wear rubber-soled shoes. It is especially dangerous to touch any switch or electric appliance in a bathroom or in any place where they may become damp; for water conducts electricity and a damp switch can give a fatal electric shock. Always switch off current before removing a plug from its socket and see that the covering of electric wiring is kept in good condition. It is better to be safe than sorry.

WHAT IS ELECTRICITY?

Hang a stick of sealing wax by a thread (Fig. 1). Rub one end of it on a piece of woollen material or on a piece of fur and, when it is still, rub another stick of wax with the same material and bring it near to the hanging wax. What happens? Now, warm a glass rod and a piece of silk. Then hold the rod with a leather glove and rub it with the silk and bring it near to the hanging wax. Again note what happens.

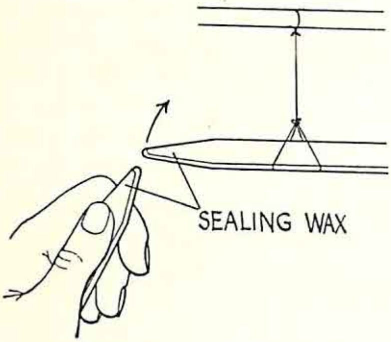

Fig. 1. Repulsion of like charges

When both pieces of wax were rubbed with the same material, they received the same electrical charge and so they repelled each other. When the glass rod was rubbed with fur it received a different electrical charge and so the rod and the wax were attracted to each other.

So, it seems that *substances with like charges repel each other* and *those with unlike charges are attracted to each other.*

When the wax was rubbed with wool it became *negatively charged.* On the other hand, when the glass rod was rubbed on silk it became *positively charged.*

If you comb your hair in the dark after a hot, dry day, you may see sparks flash between the comb and your hair. Bring the comb near to some very small pieces of dry thin paper and see what happens to them.

Rub a fountain pen on a piece of wool or fur and similarly test it with some pieces of paper.

Rubbing the pen produced forces which attract the paper. Generally, when you hold up a piece of paper and let it go, it falls to the ground, attracted or drawn towards the earth by the force of gravity. The rubbed pen however can lift the paper off the ground: so it is clear that the force produced by rubbing is greater than the force of gravity.

What is this strange force which has been known for so long and is now used in so many ways? It is clearly something with which we can do work: it is a kind of energy.

You will have seen wires carrying electricity to the places where it is needed. We speak of electricity flowing along the wires. If you cut one of the wires however and look at it you cannot see any holes in it so it does not seem that electricity flows in the wire as a liquid or a gas flows through a pipe.

Electricity is the movement of electrons. It has been said that all electrical currents are caused by the slow travel of many millions of electrons along the wire which carries the current.

An electron is a very small and almost weightless particle of matter which carries a negative electrical charge. In most substances electrons are firmly held in their atoms and so such substances are not able to conduct electricity: for example, rubber and glass. In others, such as silver, copper and aluminium which are good conductors, some electrons seem to be held less firmly within the atoms and they may be able to jump from atom to atom or to move between the atoms; and, in some way, to produce the flow of electrical charges.

THE COLLECTION OF ELECTRICAL ENERGY

We can get electricity—that is, a movement of electrons—from atoms in several ways. It can be collected:

(i) by rubbing two materials together (that is, by friction);
(ii) by chemical action in which electrons move from the atoms of a metal, which is the negative pole of an electric cell, to a positive pole where they combine with other atoms, setting free electrons; and
(iii) by means of magnets which free electrons to move in a metal wire.

A. FRICTIONAL ELECTRICITY collected by rubbing two materials together is called *Static Electricity*. Static means standing still. Frictional electricity is collected on something and remains on it until it can escape: just as water remains in a tank until a tap is turned on or the water can get out in some other way. The amount of electricity which can be produced by rubbing is not enough for street lighting or other practical purposes. It is mainly useful because it helps us to see how positive and negative electrical charges behave.

SOME EXAMPLES OF STATIC ELECTRICITY GENERATED BY FRICTION

(1) An electroscope is an instrument for noting small charges of static electricity. You can make one by passing a piece of copper wire or a copper rivet through a rubber bung and

fixing the bung in the centre of the screw top cover of a jam jar. Cut a small slit in the lower end of the copper rivet and in the slit place the folded end of a piece of 'silver paper' (used for wrapping chocolate): ordinary thin writing paper is also satisfactory (Fig. 2).

Put a charge on to a piece of sealing wax or a long plastic rod by rubbing it on fur and bring the wax near to the top of the copper rivet. Touch the rivet. What do you see inside the jar?

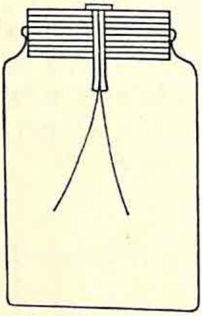

Fig. 2. An electroscope

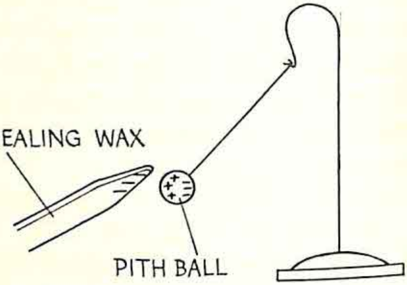

Fig. 3. Attraction of opposite charges

The reason for the movement of the two ends of the paper is simple. The wax had been given a negative charge. It therefore induced a positive charge at the nearer (that is, the top) side of the copper rivet, while the negative electrons in the copper fled to the far side (i.e. the bottom). So both pieces of paper were given a negative charge and, as like charges repel, they both sprang apart.

(2) Hang a table tennis ball (or a grain of puffed maize) by a thread. Bring a charged wax rod near it, and note the behaviour of the ball (Fig. 3). When the wax came near the ball, the charged electrons on the wax repelled the free electrons on the near side of the ball, leaving a surplus of positively charged particles which were strongly attracted by the negative charge on the wax. So the ball was attracted to the wax. The free electrons all went to the opposite side of the ball. So we say that an electrical charge induces an opposite charge on the nearer side of an uncharged body and a like charge on its far side.

(3) Fill a small rubber balloon or a bladder with air. Rub it with a piece of fur or woollen material. Rubbing causes it to pick up some electrons from the wool and so to become nega-

tively charged. (Before it was rubbed the atoms in the rubber had an equal number of positive and negative charges: the rubber was electrically neutral. After being rubbed there are more negative than positive charges in some of the atoms of the balloon; it has become negatively charged.) Now place the balloon against the plaster of the school wall. Take your hand away from the balloon and watch what happens to it. What do you learn about the electrical state of the wall? Note how long the negative charge remains on the balloon.

(4) Turn on a water tap and then turn it off slowly until there is only a very thin stream of water falling from it. Then rub a comb or a piece of sealing wax on wool and hold it about a quarter of an inch from the falling stream of water. What happens to the water? Has the water an electrical charge and is it positive or negative?

NOTE: *These experiments with frictional electricity are best done when the air is very dry.*

In dry weather the friction of the air on moving objects such as motor cars and aeroplanes causes static electricity to collect on their surfaces. This can be very dangerous. For if a large charge is collected on anything it will jump across the gap when something else is brought near, making a spark which can be seen and a cracking noise which can be heard. This may happen when a man steps from a car after driving through very dry air. If he touches the surface of the car a spark can leap from it to his hand which might even start a petrol fire. So you may sometimes see a small chain hanging from the back of the car. It touches the ground occasionally and static electricity escapes to the earth. Aeroplanes in the tropics sometimes have small brushes at the end of the wings, setting free the electricity collected by friction and so reducing the danger from the very high electric charges which can be collected on the metal surfaces.

In a thunderstorm very large electrical charges collected by the friction of the air on the drops of water in a cloud jump across between clouds at different levels or between clouds and the ground. As the electric spark passes from one cloud to another or to earth it produces the bright flash of lightning and a loud cracking sound. It is the echoing of this sound which we hear as the rolling peal of thunder.

B. ELECTRICAL ENERGY SET FREE BY CHEMICAL ACTION

The quantity of electricity which can be collected by rubbing is very small; though, as you can see, when it strikes and kills a tree it may be very powerful. To light our houses or to drive electric motors we need larger quantities of less powerful electricity.

Useful small amounts of electrical energy can be obtained by chemical action. Any chemical apparatus in which this is done is called an *electric cell*. Cells are used for collecting low power electricity for such things as hand lamps. They are too costly for lighting a whole town for they use up metals which are expensive. So when we need large amounts of electricity we burn cheap coal, oil or wood in power stations to collect or, as we say, to generate it.

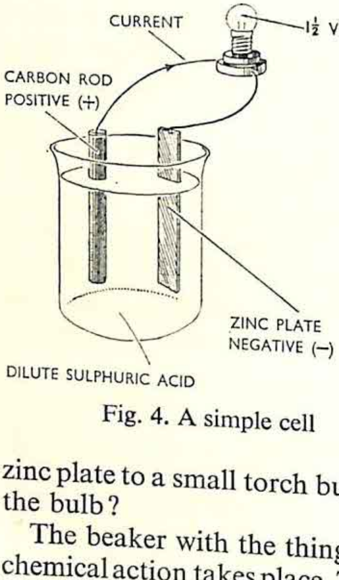

Fig. 4. A simple cell

Take the black carbon rod which you will find in the centre of an old torch battery and place it and a piece of zinc in a beaker of dilute sulphuric acid. Then connect the carbon rod and zinc plate to a small torch bulb (Fig. 4). What happens inside the bulb?

The beaker with the things in it is an electric cell. In the cell, chemical action takes place. The zinc combines with the sulphuric acid to produce the compound, zinc sulphate. Electrons are set free and the zinc plate becomes negatively charged. The carbon rod becomes positively charged. When the carbon and zinc are connected to the torch bulb an electric current flows and it is seen as light. We say that the electric current flows from the positive to the negative side of the cell: this is an electrical circuit.

As you may see, the light in the lamp soon fades for the carbon becomes covered by little bubbles of hydrogen which stop the flow of electricity. When a cell is blocked by hydrogen we say that it is polarised. So ways have been found to get rid of the hydrogen which would make the cell useless. Cut a torch battery in half (see Fig. 5). The whole case of the cell is made of zinc and is the negative pole of the cell. Instead of sulphuric acid, which you used in the beaker, there is a paste containing ammonium chloride. Around the carbon rod, the positive pole of the cell, there is a bag containing another paste (a mixture of carbon and manganese dioxide) which slows up the formation of hydrogen bubbles on the carbon. Note that although torch batteries are called *dry batteries* they are not dry. They would not work if they became really dry.

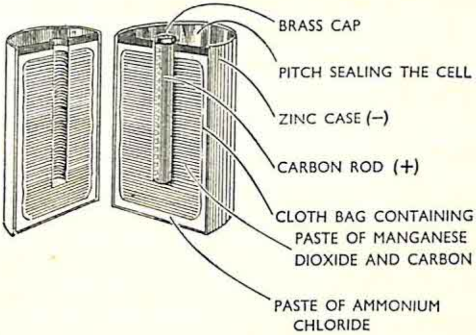
BRASS CAP
PITCH SEALING THE CELL
ZINC CASE (–)
CARBON ROD (+)
CLOTH BAG CONTAINING PASTE OF MANGANESE DIOXIDE AND CARBON
PASTE OF AMMONIUM CHLORIDE

Fig. 5. A dry cell cut in half

ELECTRIC CURRENT, VOLTS, AMPS AND WATTS

The movement of electrons through the wire from one pole of the cell to the other is an electric current. We talk of elec-

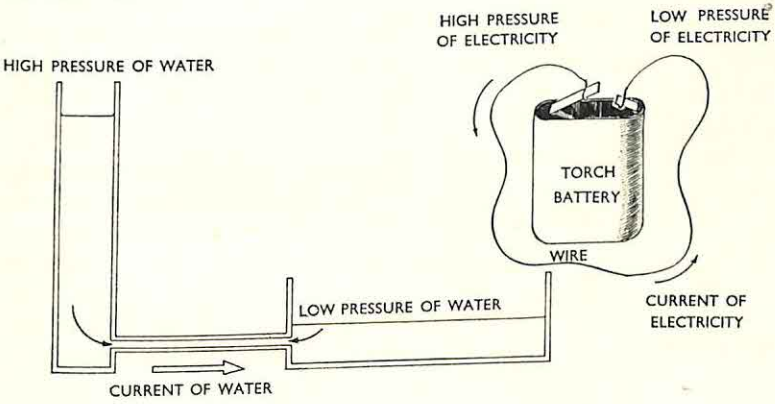

Fig. 6. The flow of water and electricity

tricity flowing through wire as if it were water flowing through a pipe. It is convenient to do so, for in many ways the two things are similar. Water flows through a pipe when there is a higher pressure at one end than at the other end (Fig. 6). Electricity flows through a wire when there is a greater pressure at one end than at the other. We measure electrical pressure in *Volts*. The amount of electrical current flowing is measured in units called *Amperes or amps*. Water flows more easily and quickly through a broad than through a narrow pipe. Similarly, a thin wire resists the flow of electricity but large currents flow with little resistance through thick wires. The amount of resistance in an electric conductor is measured in *Ohms*. The speed at which electric current is used is measured in *Watts*. The watt is a unit of power: a 100 watt bulb gives twice as bright a light as that given by a lamp using 50 watts. *An Electric Circuit* is the complete path followed by an electric current. Generated in a power station by burning coal and other materials brought up from the Earth, the electric current flows along conductors to the places

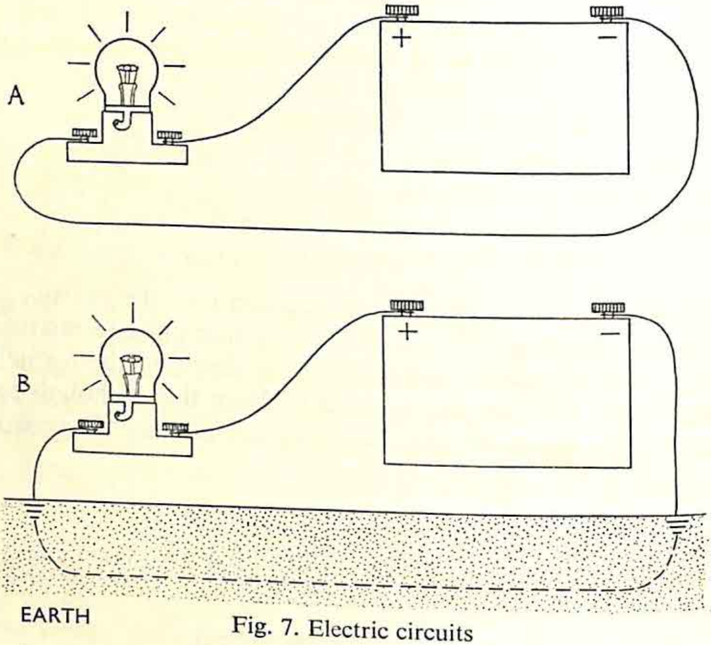

Fig. 7. Electric circuits

where it is put to work and then either returns to the power station to be given new energy or returns to Earth.

In many circuits (Fig. 7) there is one wire from the source of electricity to the place where it is being used, for example, in a lamp, and another wire back to the source. This is a circuit in which the whole path may be seen. Often however the circuit may take the second form shown, where electricity seems to be coming from and returning to the Earth and where the Earth, a vast store of electrons, is used as one side of the circuit. Ask a motor mechanic to show you how a 6-volt car battery and the car lamps are both 'earthed' in this way (that is, they are connected to the metal frame of the car).

At the beginning of this section a circuit was defined as the complete path of an electric current. Note that electricity only flows when the circuit is *complete*. Therefore all connections in a circuit must be clean and well made. Connect a 1½ volt cell and a lamp as in Fig. 8. Does the lamp light? Do you ever stop to marvel at this wonderful thing, an electric lamp? Now disconnect the circuit at any point. What happens?

An earthed circuit behaves in the same way. If the connection with the earth is not well made, there is no circuit and no flow of electricity. Any mechanic can show you that rust and dirt are frequent causes of breaks in circuits.

A CIRCUIT IN SERIES

The single cell using zinc, carbon and acid to produce current for hand lamps gives an electric pressure of 1½ volts. When we want more power we can connect two or more dry cells together with the positive central terminal connected to the negative zinc case of the next cell. Cells connected in this way are said to be in *series* and to form a *battery* (Fig. 8). They are similar to three pumps working together and pumping more water than one of them alone.

Connect three 1½ volt cells in series and put a small lamp holder with a 4½ volt bulb in the circuit. Note the bright light.

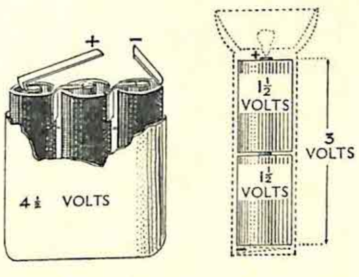

Fig. 8. Cells in batteries (in series)

Take away one cell, leaving two cells in the circuit. What happens to the light? Take away another cell, leaving only one in the circuit and note the effect on the bulb.

Batteries used for radio receivers and for other purposes are sometimes made by connecting large numbers of single dry cells in series. A battery containing a hundred cells would give a pressure of 100 × 1½ volts.

A CIRCUIT IN PARALLEL

Take three new 1½ volt cells and connect them as in Fig. 9. Linked in this way they are like three pumps helping each other but *not* pumping more water. The central positive terminals of each cell are joined together, as are the bottoms of the three zinc cases. We say that the cells are now connected in *parallel*.

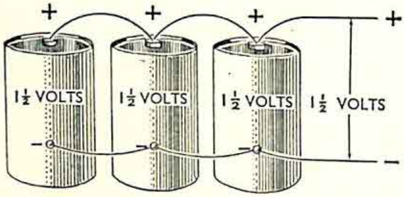

Fig. 9. Cells in parallel

Connect the wires from the cells to a lamp holder in which there is a 1½ volt bulb. Note the brightness of the light. Take away one of the cells. Connect the remaining two cells (in parallel) to the lamp. Is there any difference in the brightness of the light?

Take away another cell leaving only one cell in circuit with the lamp. Is the light still bright?

When cells are connected in parallel the total voltage of the circuit is not increased—but the length of life of the circuit is multiplied (× 3 in this case).

SOME MORE EXPERIMENTS WITH CIRCUITS

Set up three 1½ volt bulbs in series (Fig. 10) and connect them to a single cell. Unscrew one of the bulbs. Why do the other two lamps go out?

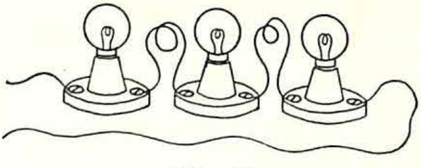

Fig. 10.
Lamps connected in series

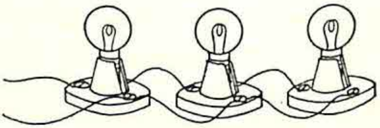

Fig. 11.
Lamps connected in parallel

Set up the same three lamps in parallel (Fig. 11) and connect them to one cell. Unscrew one bulb. Why do the other two lamps now remain alight?

Set up two cells and a lamp so that each terminal on the lamp holder is connected to both a positive and a negative source of electricity (Fig. 12). If two pumps work against each other no water is raised. Similarly, in this circuit, no light is produced because the two cells oppose each other.

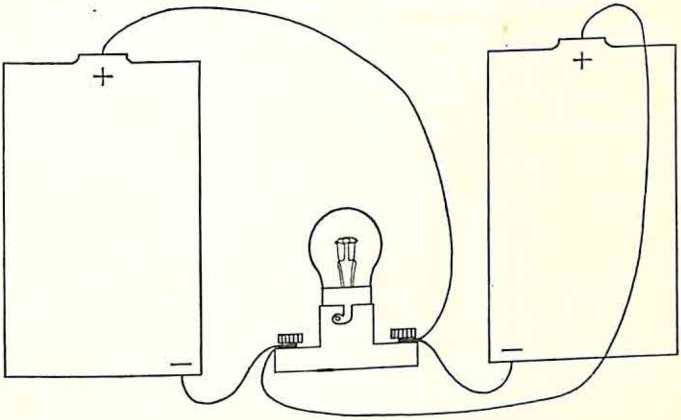

Fig. 12. Cells in opposition.

Put a switch into a circuit with one cell and lamp (Fig. 13) to control the flow of electric current. A simple switch can be made as shown with a pencil, to which one of the wires is tied.

The points on an electric apparatus to which conducting wires are fixed are called the positive and negative terminals. The positive terminal is sometimes painted red and marked with a + sign. The negative terminal is sometimes painted black and marked with a − sign. The wires conducting current in an electric circuit are called *the leads* (pronounced: leeds).

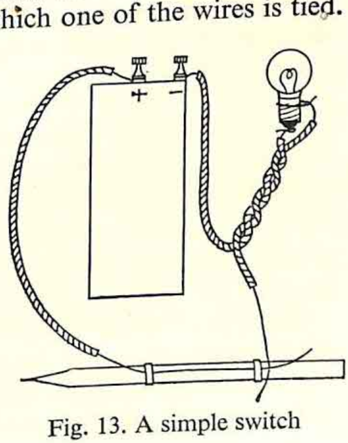

Fig. 13. A simple switch

ELECTRICAL CONDUCTORS

Use the apparatus shown in Fig. 14 to test whether various substances are conductors of electricity. On a piece of wood (12 ins. × 4 ins.) mount a $4\frac{1}{2}$ volt battery, a lamp, a switch, and two pieces of metal (brass or tinned iron). Connect these with a circuit of flexible covered wire and extend the wires from the two pieces of metal and solder their other ends to two 4 in. nails firmly held in a two-hole rubber or cork stopper.

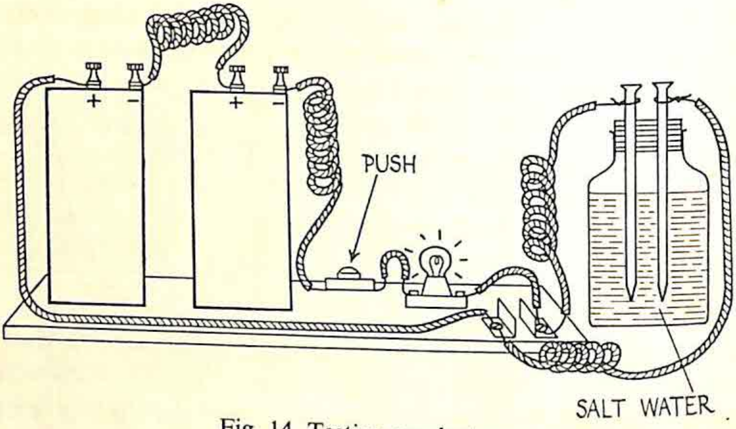

Fig. 14. Testing conductors

Test the conductivity of any solid material by laying it across the top of the metal strips and then pressing the switch.

Test the conductivity of any liquid by placing some of it in the bottle and then lower the nails into it. Test palm oil, distilled water and solutions of soap, common salt, Epsom salt, sugar and copper sulphate.

ELECTRICAL INSULATORS

Materials which are not conductors can be used to prevent the loss of an electrical current flowing in a conductor. They are said to insulate the conductor (Insula is the Latin word for 'an island'). They are insulators. Make a list of materials used as electrical insulators.

THE STORING OF ELECTRICITY

A group of two or more dry cells as used in an electric hand lamp is known as a *primary* battery. In them, as you have seen, acid acts on zinc and electrons are set free. Even more important, however, are the *secondary* batteries or *Accumulators* used, e.g. in motor cars for storing electricity received from a generator. Ask a mechanic to show you the generator and the storage battery and the electric circuit connecting them.

You can see how an accumulator works by tying two pieces of lead about an inch wide and four inches long, one on each side of a somewhat longer piece of wood and placing them in a beaker containing dilute (40%) sulphuric acid and water. Connect the two pieces of lead to a 1½ volt torch bulb. Does the bulb light up? Now connect the pieces of lead to a battery of three or more dry cells in series (Fig. 15). Note what happens to the lead in the dilute acid. Electrical energy from the cells is being stored in the accumulator. After ten minutes, disconnect the dry battery and connect the pieces of lead again to the torch bulb. What do you see? The accumulator is giving out the electricity which has been stored in it. Recharge it; then leave it all night and test it.

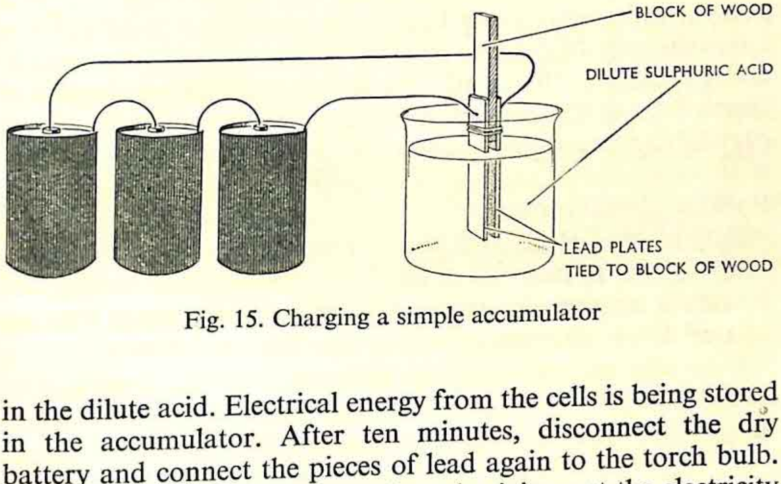

Fig. 15. Charging a simple accumulator

The storage batteries used in motor cars work in the same way as this simple accumulator but they usually contain three or six pairs of cells connected in series. Each cell is capable of storing 2 volts of electricity. The storage battery provides the energy for making the spark which causes the gas to explode inside the cylinder of a motor car engine. The engine, in turn, provides the energy to drive a generator which puts electricity back into the battery.

C. ELECTRICAL ENERGY SET FREE BY MAGNETS

You have seen that we can get some electricity by rubbing some things and that we get a lot of electricity from the chemical action of some acids on some metals. We now come to the most important source of electricity, the movements of magnets.

For more than 2,000 years men have known that there were pieces of rock, called lodestones, which were able to attract iron and which if floated on water always turned and set themselves in a particular direction. We call such lodestones, *Magnets*. (Magnesia was the name of the place from which the Greeks used to get such stones). It was soon found that if a piece of steel was stroked with a lodestone it also became a magnet. Nowadays, we generally use steel for magnets. You will find that if you tie a silk or cotton thread to a magnet and let it hang freely it will always swing to and fro until it sets itself pointing approximately North and South. The same end of the magnet always points to the North. We call that the North seeking or North Pole of the magnet. The other end is the South seeking or, as it is more usually called, the South Pole.

MAKING A MAGNET

Any piece of steel, such as a needle, a bicycle spoke, a safety razor blade, a piece of a clock or gramophone spring, can become a magnet. Stroke one pole of a magnet along the piece of steel *in one direction only* (Fig. 16). Repeat this movement at least twenty times. Hang up your new magnet. Put a spot of black paint on the North Pole and some red paint on the South Pole—or mark them in some other way.

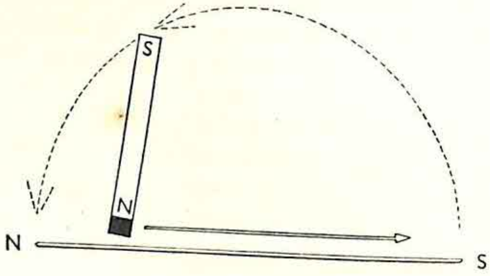

Fig. 16. Making a new magnet

It is not easy to explain what happens when iron is magnetised. It seems as if all the atoms packed together along a piece of iron are in small groups each of which, like a compass needle, is able to swing freely and is set in any direction (Fig. 17). When the piece of iron is stroked with the North pole of a magnet all

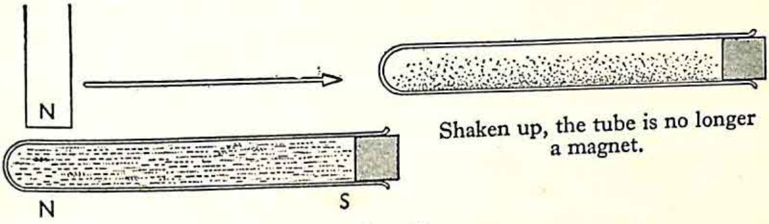

Fig. 17.

the North poles of the small atomic compass needles are turned away: all the little compass needles are set in the same direction and the piece of iron is magnetised. In iron, however, the small compass needles soon start swinging freely again and the iron ceases to be a magnet. In steel the groups of atoms are more firmly held together than in iron so that when all the particles have been forced by the stroking to point North and South they stay that way until an equal force is used to disturb them. So steel tends to keep its magnetic power.

THE ATTRACTION AND REPULSION OF MAGNETIC POLES

Let the magnet which you made, hang freely and wait until it sets in a North-South direction. Now, hold another magnet near it and find out what happens when:

(i) a North Pole is brought near a North Pole,
(ii) a North Pole is brought near a South Pole,
(iii) a South Pole is brought near a North Pole,
(iv) a South Pole is brought near a South Pole.

You may repeat these experiments with one magnet on a cork, floating in water (in a non-metal container).

You will find, as you did in the experiments with static electricity, that unlike poles attract each other and like poles repel each other.

SOME EXPERIMENTS WITH MAGNETS

(1) Place one of the magnets you have made among some iron filings, tin tacks or steel pins. You will see that they are attracted to the two poles of the magnet.

(2) With one end of a bar magnet pick up a nail. Bring the end of the nail near to another nail. Can the first nail pick up the second nail? (Fig. 18). The magnet is said to *induce* or put magnetism into the first nail. Perhaps you may be able to induce magnetism into a string of nails in this way. Remove the magnet: what happens to the nails?

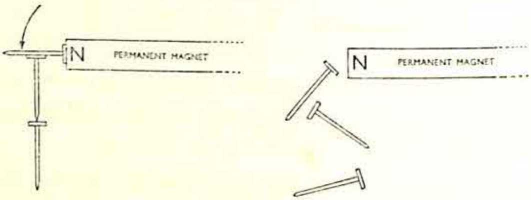

Fig. 18.

When the permanent magnet is removed, the nails drop off. The large nail was a temporary magnet.

(3) Put the eye of a needle at the North pole of a magnet. Bring the North pole of another magnet near to the point of the needle. What happens?

(4) Use a bar magnet to lift materials which are attracted by it.

(5) Find out whether a magnet is able to attract things through glass and through other materials, such as wood and cardboard.

(6) Place a small bar magnet on a table. Bring a large nail or an iron bolt near to the magnet. Is the magnet attracted to the nail? Can the magnet be lifted by the nail?

(7) Fix a magnet in a clamp (Fig. 19) and note how it attracts a paper clip fastened

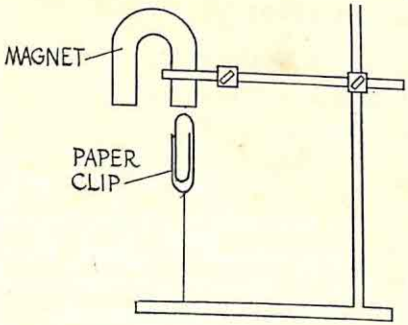

Fig. 19. Magnetism and the force of gravity

to the base by a thread. The force of the magnet is clearly greater than the force of gravity. Put sheets of thin iron, glass and other materials between the magnet and the clip and note what happens.

(8) Test the strength of a magnet by finding out what weight it can lift.

CAN MAGNETISM BE DESTROYED?

Magnetise a long steel needle and mark the two poles. Then, holding it with two pairs of pliers, break it in the middle. Do you now have two magnets, each with only one pole? Float the two pieces on corks in water and test each end of each piece of needle.

Take one of the magnets which you have made. Test it to be sure that it is still acting as a magnet. Then hammer it on an anvil or some other hard surface. Now test it again to see whether it still attracts steel pins and iron filings. Stroke the steel again, at least twenty times, with one pole of a permanent magnet and then test the magnet you have made. When you are sure that it is acting as a magnet, put it in a flame and heat it well. When it is cool, again test it to see whether it still attracts iron filings, steel pins, etc.

Stroking the steel with one pole of a magnet caused the positive and negative electrical particles in the atoms of which the steel is made to arrange themselves in an orderly manner. Hitting the steel or heating it caused the particles to become disorderly again.

Note: A permanent magnet should be treated carefully. If it is dropped on the floor its magnetic power may be destroyed.

THE MAGNETIC FORCE OF AN ELECTRIC CURRENT

Do the experiment shown in Fig. 20. Then change the position of the wires so that the current flows in the opposite direction. Note what happens to the compass needle in each case. This effect of a current on

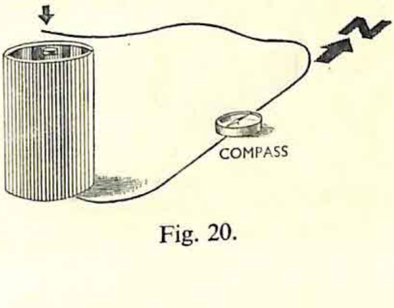

Fig. 20.

a magnet is used in instruments for testing the strength of electric currents: ammeters, voltmeters, etc. It is also used in a simple tool which you can make yourself for indicating the flow of an electric current.

A SIMPLE CURRENT INDICATOR

Get an old ignition coil from a motor mechanic. Cut away the outer case with a hacksaw and then put the coil in a tin and heat it to melt off the tar.

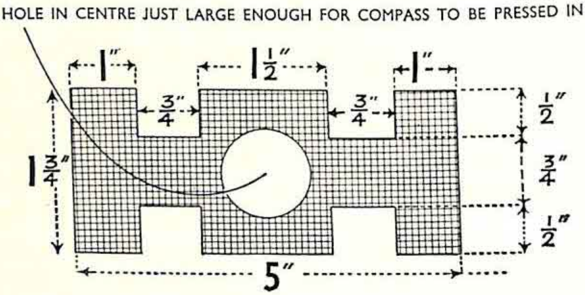
HOLE IN CENTRE JUST LARGE ENOUGH FOR COMPASS TO BE PRESSED IN
1"
1½"
1"
¾"
¾"
1¾"
½"
¾"
½"
5"

Fig. 21.

Cut a piece of wood, 5 ins. by 1¾ ins. by ½ in. as shown in Fig. 21.

Take the old coil and from it wind 150 turns of wire round the narrow neck at one end of the piece of wood and take the wire across the back of the wood and wind 150 turns of the wire on the other narrow part. Wind in the same direction all the

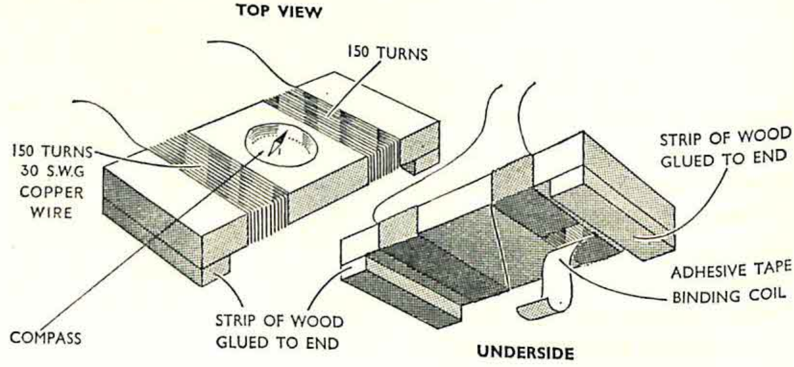

Fig. 22.

time. When you have finished winding the wire, bind the windings with some black insulation tape and nail or glue two pieces of wood to the underside as in Fig. 22.

Take the free ends of the wires to a 1½ volt electric cell and note what happens when the current flows past the magnetised pointer in the compass.

(If you cannot get an old ignition coil or an old electric bell, use 30 s.w.g. insulated copper wire to make this current indicator).

MAGNETS AND ELECTRICITY

In the experiments which you have done with magnets you have seen that they seem to be centres of electrical energy. You have also seen that an electrical current acts like a magnet: for when it passes near a compass needle set North and South it can pull the needle away from that usual position.

Now you must see how magnets are used to collect electricity, for this is by far the most important way in which we obtain the ever increasing amount of electricity needed in the modern world.

To do this you will need a coil of insulated wire as in Fig. 23. To make the coil wrap some newspaper around a one pint bottle and wind 10 turns of insulated copper wire on to the bottle. Cover them with insulation tape and wind another 10 turns of wire on to the tape. Again cover the wire with a turn of the tape and wind on a third row of 10 turns of insulated wire. Leave a long piece of wire loose at the start and the finish of the coil. Take the coil off the bottle carefully and bind it, in four equally spaced places, with insulated tape to hold it together.

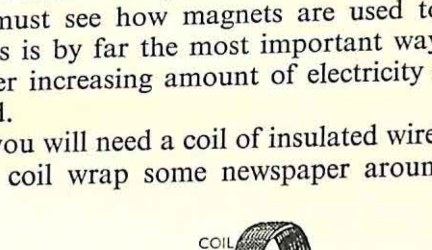

Fig. 23.

Connect the terminal wires of the coil to the Current Indicator which you made. The wires must be long to ensure that the

Indicator is *outside* the field of a magnet placed beside the coil (that is, it must be about five feet from a 6 in. bar magnet).

Lift the magnet and move one pole towards and away from the centre of the coil. Do this several times, not too quickly, and watch the needle of the compass. What do you see? Repeat, using the other pole of the magnet and note the result.

When the magnet is moved into the coil the compass needle moves, showing that an electric current is passing: when the magnet is moved out of the coil the needle of the current indicator moves in the opposite direction. You can make the needle move rapidly to and fro, by moving the magnet rapidly.

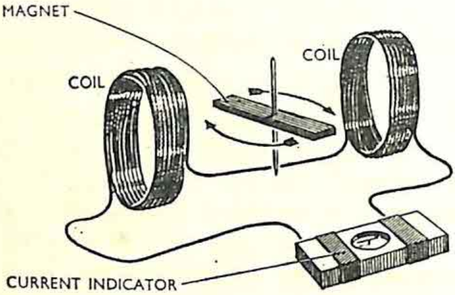

Fig. 24.

A simple generator of electricity can be made with two coils of wire and a magnet turning between them as in Fig. 24. Turn the magnet steadily and note that the needle moves to left and right in time with the movement of the magnet. The electric current in the circuit flows first one way and then the other. That is, it is *alternating current*, which is the electrical current used in most public supplies. Bicycle dynamos (generators) work in this way. Even the largest dynamos in power stations generate this form of electricity but they use many more and much larger magnets.

ELECTROMAGNETS are magnets in which the magnetic force can be switched on and off. You have seen that an electric current flowing through a wire has some magnetic force: that a compass needle placed near the wire is attracted when the current flows in the wire. A current flowing through a wire wound into a coil is even more attractive and the coil acts as a bar magnet.

Use one of the coils which you have made and pass a current from a 1½ volt electric cell through it. Place a compass near to the coil to show that, when the current flows, one end of the coil is the South Pole and the other end is its North Pole.

Wind some thirty turns of insulated copper wire on to an iron bolt (approx. 6 ins. by ½ in.) and bind the wire with some insulating tape. Lead the ends of the wire to the poles of a 1½ volt cell. When current is passing through the wire bring one end of the bolt near to a steel pin. What happens to the pin? See how many pins, joined end to end, it will pick up.

Then stand two cells on top of each other (that is, join them in series) and see whether the electromagnet will pick up a longer string of pins.

What happens to the pins if the flow of current is suddenly stopped? Is there any magnetic force in the bolt when no current is flowing?

(You may find that there is still a small amount of magnetic force left in the iron bolt after the current has been switched off. This is because the iron is not sufficiently pure. In electric motors and other machines using electromagnets, the cores are made of thin sheets of very pure iron: so that the magnetic force may be switched on and off completely and rapidly.)

Electromagnets are used for many purposes. An electromagnet is the easiest way by which an electric current can be made to do something at a distant place. A visitor comes to the door, he pushes a button and a bell rings far inside the house. Examine the working of an electric bell: note how pressing the button causes a current to flow through an electromagnet which attracts the striker. Electromagnets, working at high speeds, are also used in telephone and radio speakers to make the sound waves of speech.

A simple electric motor can be made in this way: Set up the coil and compass as in Fig. 23 and put a 1½ volt dry cell in the circuit. With the bared end of one wire, tap the top of the dry cell regularly in time with the turning compass point (like a drummer tapping a drum for a dancer). If you are skilful you will be able to keep the compass needle spinning round and round. You have changed electric energy into mechanical energy.

Of course, in a real electric motor you do not have to switch the current on and off in that way. In an electric motor the electromagnets are fixed and it is the coils (called 'the armature')

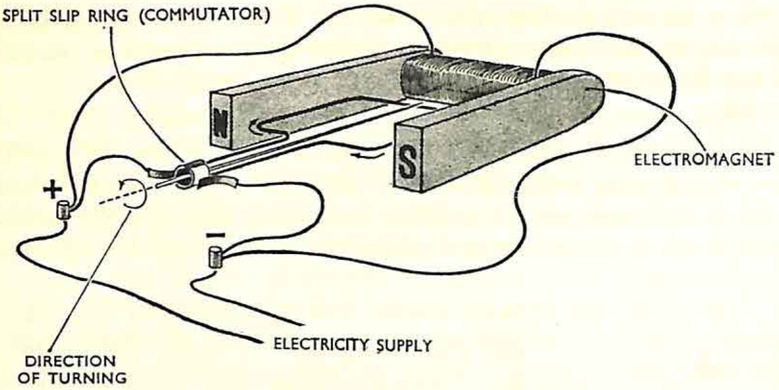

Fig. 25.

which turn between the poles of the magnets (Fig. 25). The current is led to the coils through carbon 'brushes' and it is switched on and off by the slip ring (commutator).

Open up an old electric fan motor to see these parts.

OVERHEATING IN ELECTRIC CIRCUITS

Take two feet of insulated bell wire and remove about three inches of the covering in the middle and an inch at each end of the wire. Place the bulb of a thermometer at the centre of the length of wire and *carefully* wind the bare wire round it. Cover the wire and bulb with insulating tape. (Be careful not to heat the bulb by touching it with your fingers.) Note the temperature of the thermometer. Bring the free ends of the wire into contact with the terminals of a 4½ volt battery. Watch the mercury in the thermometer and record the temperature change.

At about seven feet above ground level, stretch a length of insulated bell wire across a room, fastening the wire firmly at each wall and bringing the free ends of the wire down to the ground. From the centre of the wire hang a thread, lightly weighted and carrying a horizontal pointer. Note its position and then connect the free ends of the bell wire to the terminals of a 6-volt car battery. After some minutes again note the position of the pointer. The wire has expanded because it has been heated.

These experiments will have shown you that when an electric current passes through a wire, the wire is heated. Sometimes this is useful; for example, when we wish to heat water in an electric kettle. Often, however, it can cause heavy loss: houses have been destroyed due to overheated wires setting fire to timber.

Electric wires become overheated if too many appliances (lamps, kettles, fans, heaters, etc.) are put on to one power point. More current is used than the wire is able to carry safely. There is too much electrical pressure in the wire and it becomes overheated.

Electric wires can also become overheated if their insulation breaks down. Then two wires may touch and there is a 'short circuit'. Electric current flowing through the wires used in a house circuit always meets with some resistance from the metal: if the circuit suddenly becomes shorter, the resistance in the circuit becomes very much less and a very large current flows which may make the wires red hot and start a fire.

Electric kettles and other electric tools have a positive and a negative wire making a circuit with the generating station which is the source of electricity. They should also have a third wire which is connected to earth. This is a safety wire. It carries current direct to earth if there is a short circuit due to a fault in the insulation or to any other cause. If there is a short circuit through an electrical apparatus which has no earth wire, anyone who touches it may be killed as the current passes through his body to earth.

The insulation of electric wires breaks down in the tropics very easily: heat causes rubber to 'perish' and there are many animal pests which may damage it. Therefore electric wires should be enclosed in iron pipes and circuits should be protected by *fuses*. Fuses are short lengths of wire of higher resistance than the supply wires, fixed so that all current flows through them. If the circuit is becoming overheated, the fuses (being made of soft wire of high resistance) burn out before the supply wires become dangerously hot. *If a fuse burns out, always try to find the cause of the overheating. Never put two pieces of fuse wire or a piece of wire of lower resistance, e.g. a piece of ordinary supply wire, in place of the fuse.*

So, this chapter ends with the same warning with which it began. Electricity is a very valuable servant but it can be extremely dangerous if it becomes the master.

SUMMARY

You have learned that electricity is the flow of very small particles called electrons. Three ways of collecting electrons (friction, chemical action and the movement of magnets) were examined. Experiments with various circuits, with magnets, with various electrical conductors, insulators and accumulators were described. At both the beginning and the end of the chapter the dangers of handling and using electricity carelessly were stressed.

MORE THINGS TO DO

(1) Take an old bicycle dynamo to pieces to see how it works.

(2) Make a drawing of the circuit in an electric torch.

(3) Make a floating compass.

(4) Cut a new torch cell in half along its length with a hacksaw (without cutting the carbon rod in the centre). Will half a cell light a bulb? Bake one half of the cell and test it with a lamp bulb. Is a 'dry cell' really dry?

(5) Open up an old car battery carefully to see how the plates are connected inside.

(6) Using thin insulated bell wire, put an electric bulb in circuit with a 1½ volt dry cell. Test the light. Then increase the length of one wire between the cell and the bulb to at least 5 yards. What difference is there in the brightness of the light and what is the reason?

QUESTIONS

(1) Why do some substances conduct electricity better than others? For what purpose can a substance which is a bad conductor be used?

(2) How can an electromagnet be used in an electric bell.

(3) Three lamps are connected in series to a 6-volt battery and three lamps are connected in parallel to a similar battery. Which lamps will give the brighter light and which will last for the longer time?

(4) How is telegraph wire insulated?

(5) What is a lightning conductor?

(6) How can it be seen that an electric current is passing along a conductor?

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